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IMF-600 IMPEDANCE

AND MULTIFUNCTION METER

INSTRUCTION AND SERVICE MANUAL

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AND MULTIFUNCTION METER

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WARNING

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OBSERVE ALL SAFETY RULES WHEN MEASURING HIGH VOLTAGES OR LINE VOLTAGES.

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EXERCISE CAUTION WHEN APPLYING A HIGH BIAS VOLTAGE.

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DO NOT CONNECT THE IMF COMMON TERMINAL (ON REAR PANEL) TO EXTERNAL GROUND WHEN MEASURING A SIGNAL REFERENCED TO THAT EXTERNAL GROUND.

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DO NOT APPLY ANY TEST VOLTAGE OR CURRENT GREATER THAN SPECIFIED.

DO NOT TEST CAPACITORS WITH A CHARGE GREATER THAN SPECIFIED.

DISCHARGE CAPACITORS AFTER APPLYING A BIAS VOLTAGE.

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1.0 INTRODUCTION

1.1 Description

The IET Labs IMF-600 Impedance and Multifunction Meter (Figure 1.1) is an automatic instrument for measurement of the following quantities:

CAPACITANCE	)
CONDUCTANCE	)simultaneously
DISSIPATION FACTOR (D)	)
INDUCTANCE	)
RESISTANCE	)simultaneously
QUALITY FACTOR (Q=1/D)	)
DC VOLTAGE	
DC CURRENT	
AC VOLTAGE (true RMS)	
AC CURRENT (true RMS)	
FREQUENCY	(optional)

This versatile instrument can be used as a digital multimeter in addition to being a convenient "unknown" measuring device. Virtually any passive component may be categorized in terms of a simple or complex impedance.

All that is required to measure an unknown quantity, is to connect the 4-terminal Kelvin leads, to press the appropriate pushbutton and to select a range. The quantity and the units are automatically indicated with an unambiguous 3-1/2 digit display and clear back lighted annunciators.

The 4-terminal Kelvin leads permit the measurement of very small impedances such as the resistance of wires or connectors.

Capacitors and inductors may be selected by considering their lossy component (D or 1/Q); this can be useful in discriminating between seemingly equivalent components. Capacitors or inductors may, in many cases, be measured in circuit without the necessity of removing them.

An analog output corresponding to the displayed capacitance, inductance, resistance, or conductance is provided on the rear panel; a digital BCD output, corresponding to any displayed quantity, is available as an option. Either of these outputs may be used with a companion comparator unit.

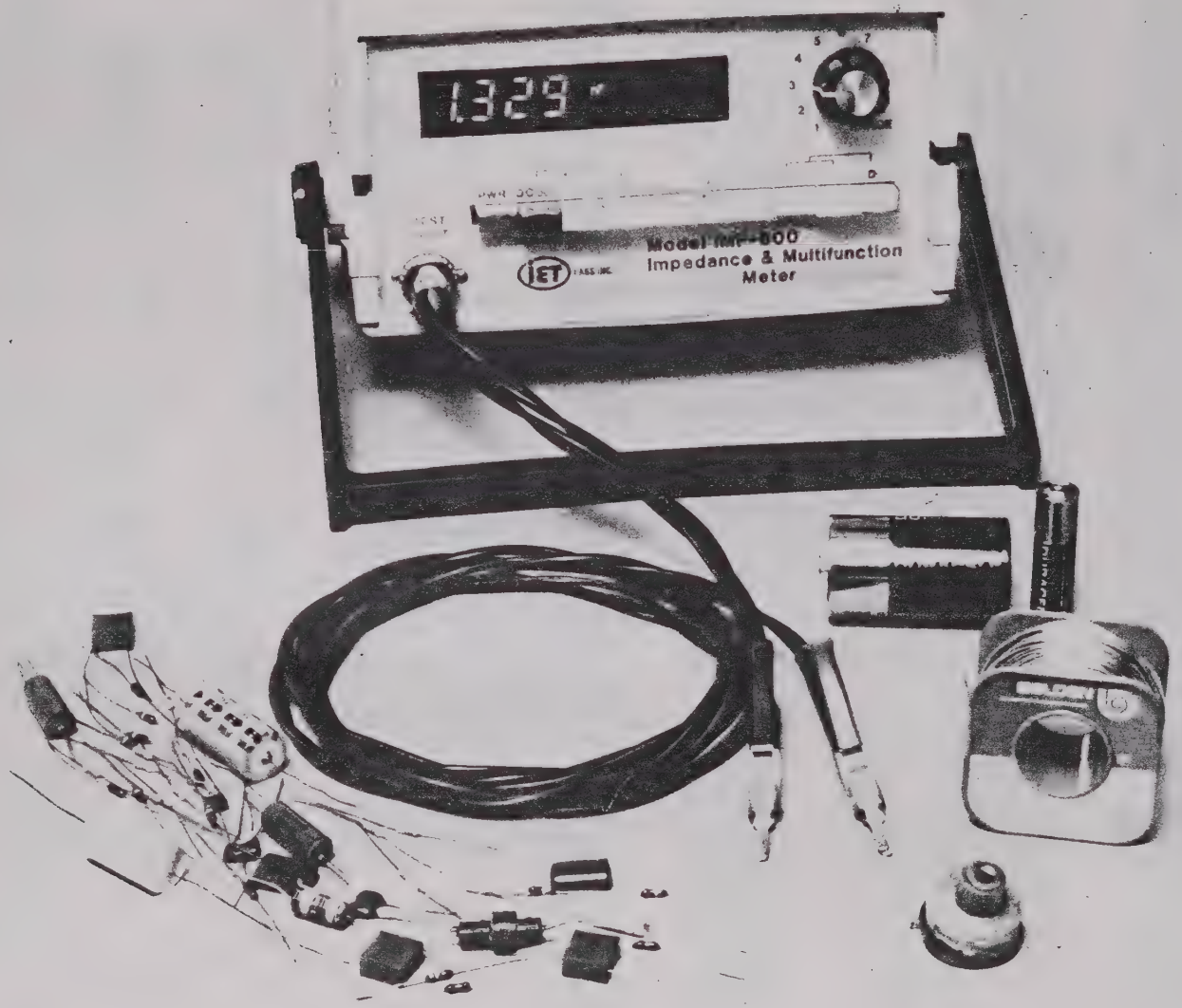


Figure 1.1 IMF-600 Impedance and Multifunction Meter

1.2 Principle of Operation

The impedance Zx of an unknown component X is defined as:

$$Zx=Vx/Ix$$

where Vx is the complex voltage across the unknown and Ix is the current through the unknown. The IMF-600 implements this computation as shown conceptually in Figure 1.2. A sine wave generator drives current Ix through the unknown Zx and standard resistor Rs in series with it. Two ac coupled differential amplifiers produce the voltages Vx and Vr across the unknown and the resistor respectively. The impedance Zx may then be computed as follows:

$$Zx=Vx/Ix$$

$$Zx=RsVx/Vs$$

Except for resistance and conductance, Zx is a complex ratio with real and imaginary components which must be computed.

In order not to introduce any errors from the computation of a ratio, a feedback control circuit is employed to maintain either Vx or Vs constant. For capacitance and conductance, Vx is maintained fixed, and the value of the unknown is determined as follows:

$$(C \text{ or } G)=a/Zx=bVs$$

where C and G are the capacitance or the conductance respectively, and a and b are constants of proportionality (different for C and G).

For inductance and resistance measurement, Vs is kept constant by the feedback control circuit, and the computation is performed as follows:

$$(L \text{ or } R)=cZx=dVx$$

where L and R are the inductance or the resistance respectively, and c and d are constants of proportionality (different for L and R).

The voltage being measured, e.g. Vx, is broken down into the "in phase" (0 degrees) and "quadrature" (90 degrees) components with respect to the test signal. These are used to provide the real and imaginary portions of the complex impedance. A pure resistance, for example, will produce only an "in phase" component, whereas an ideal capacitor will result in only a "quadrature" signal.

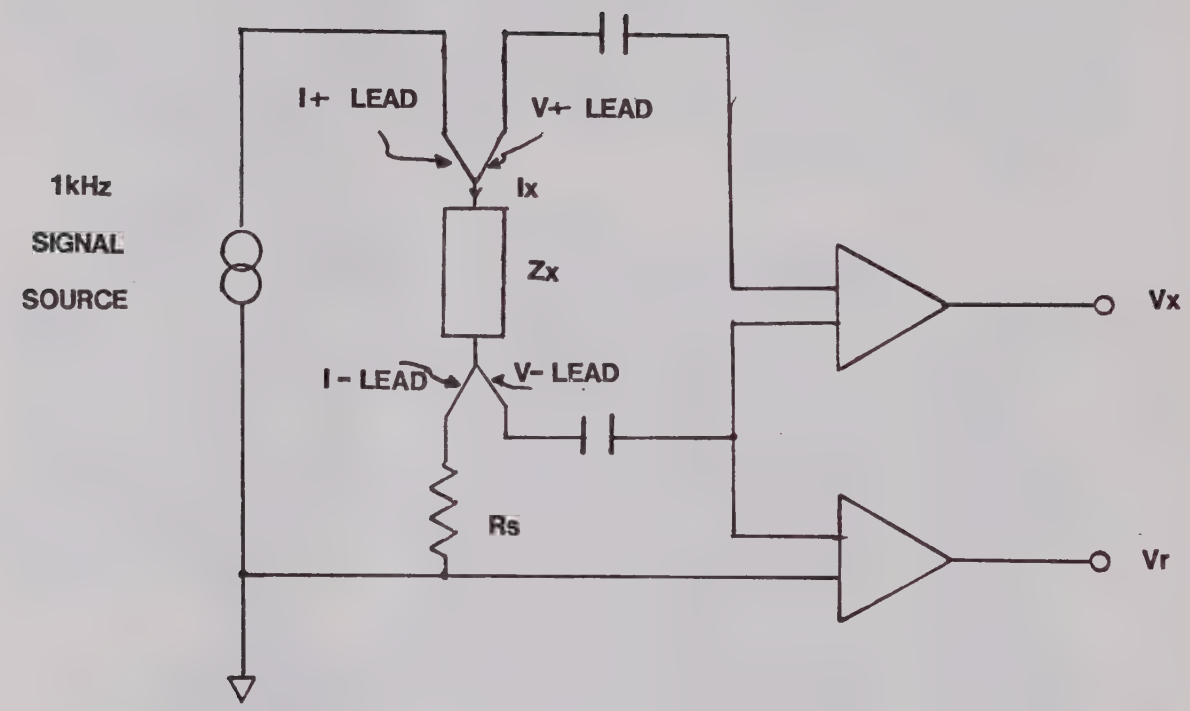


Figure 1.2 Impedance Computation Scheme

1.3 Kelvin (4-Terminal) Measurement

As may be seen in Figure 1.2, four physical conductors are actually brought out to connect to the component under test. Each two conductors are in electrical contact with each other as well as with one end of the device. They are, therefore, nominally equivalent to a single test lead. The difference becomes clear when the resistance of the test leads and of contacts are taken into consideration.

The test current is delivered to the device by leads I+ and I-. The lead pair V+ and V- are the voltage sensors which are brought directly to the component. If the voltages were sensed within the instrument, they would include the potentials developed across the current carrying leads due to their inherent resistance. Clearly, this can be very significant when measuring small impedances. Measuring the voltages right at the component eliminates this problem. The IMF-600 is therefore suitable for measuring the resistance of wire, connectors, or other "short circuits".

2.0 SPECIFICATIONS

2.1 Function Specifications

CAPACITANCE (C)

Number of ranges:	7
Full scale ranges:	200.0pF to 200.0uF; up to 20,000uF may be measured using the inductance function
Accuracy:	±(0.25%+1LSD+1% of G reading in absolute digit counts on same range); see Section 2.4
Bias:	up to 100VDC may be applied in series with unknown impedance
Test voltage:	1.4VRMS on Ranges 1-6; 0.14 VRMS on Range 7
Input protection:	220VRMS
Impedance model:	

INDUCTANCE (L)

Number of ranges:	7
Full scale ranges:	200.0uH to 200.0H
Accuracy:	±(0.25%+1LSD+1% of R reading in absolute digit counts on same range); see Section 2.4
Test current:	110mA on Range 1; 11mA on Ranges 2-3; 1.1mA on Range 4; 110uA on Range 5; 11uA on Range 6; 1.1uA on Range 7
Input protection:	220VRMS
Impedance model:	

RESISTANCE (R)

Type of measurement:	1kHz ac resistance
Number of ranges:	7
Full scale ranges:	2.000 ohms to 2000. kilohms; up to 1000 megohms may be measured using the conductance function

Accuracy:	±(0.25%+1LSD+1% of L reading in absolute digit counts on same range); see Section 2.4
Test current:	same as inductance
Input protection:	220VRMS
Impedance model:	see INDUCTANCE

CONDUCTANCE (G)

Type of measurement:	1kHz ac conductance
Number of ranges:	7
Full scale ranges:	2.000uS to 2000.mS (S=1/ohm)
Accuracy:	±(0.25%+1LSD+1% of C reading in absolute digit counts on the same range); see Section 2.4
Test voltage:	same as capacitance
Input protection:	220VRMS
Impedance model:	see CAPACITANCE

DISSIPATION (D or 1/Q)

Type of measurement:	D=G/2πfC (see impedance model) D=1/Q=R/2πfL (see impedance model)
Full scale range:	2.000; higher values may be computed from readings
Accuracy:	1%+2LSD for C or L>500 counts; 1%+4LSD for C or L 200-500 counts

DC VOLTAGE (V DC)

Number of ranges:	5
Full scale ranges:	200.0mV to 1000.V
Accuracy:	0.1%+1LSD
Input impedance:	10 megohms
Maximum input:	1000 V peak; common mode voltage (low terminal to ground: 500 V peak)

DC CURRENT (I DC)

Number of ranges: 5

Full scale ranges: 200.0uA to 2000.mA

Accuracy: 0.2%+1LSD

Burden voltage: 0.3V maximum on Ranges 1-5; 1.4V maximum on Range 5

Maximum input: 2A fuse and diode network protected

RMS VOLTAGE (V RMS)

Number of ranges: 5

Full scale ranges: 2.000mV to 750.V

Accuracy: percentage of reading + number of least significant digits

FREQ	50-100Hz	100-500Hz	500Hz-1kHz	1-10kHz	10-20kHz
200.0mV	0.5%+2	0.5%+2	0.5%+2	0.5%+2	1%+2
2.000 V	1%+2	0.5%+2	0.5%+2	0.5%+2	1%+2
20.00 V	1%+2	0.5%+2	0.5%+2	1%+2	1%+2
200.0 V	1%+2	1%+2	2%+2	-not specified-	
750. V	1%+2	2%+2	-------not specified-------		

Input impedance: 10 megohms

Maximum input: same as DC VOLTAGE

RMS CURRENT (I RMS)

Number of ranges: 5

Full scale ranges: 200.0uA to 2000.mA

Accuracy: percentage of reading + number of least significant digits

FREQ	50-100Hz	100-500Hz	500Hz-1kHz	1-10kHz	10-20kHz
200.0uA	0.5%+2	0.5%+2	0.5%+2	1%+2	2%+2
2.000mA	0.5%+2	0.5%+2	0.5%+2	1%+2	2%+2
20.00mA	1%+2	1%+2	1%+2	2%+2	2%+2
200.0mA	1%+2	1%+2	1%+2	2%+2	2%+2
2000.mA	2%+2	2%+2	2%+2	3%+2	3%+2

Burden voltage:	same as DC CURRENT
Maximum input:	same as DC CURRENT

FREQUENCY (F)-Model IMF-600F

Display:	Overrange will be indicated when the frequency option is not present.
Number of ranges:	6
Range:	100.0 Hz to 15.00 MHz; 30.0 Hz to 15.00 MHz typical
Resolution:	3-1/2 digits, may be extended to one additional least significant digit by downranging. This does not apply to Range 1 (200.0 Hz).
Gate time:	10 seconds for 200.0 Hz range 1 second for 2.000 kHz range 0.1 second for 20.00 kHz range 10 ms for 200.0 kHz range 1 ms for 2.000 MHz range 0.1 ms for 20.00 MHz range
Sampling period:	20 seconds for 200.0 Hz range 2 seconds for 2.000 kHz range 0.25 seconds for all other ranges
Impedance:	>1 Megohm, diode protected
Coupling:	AC
Sine wave sensitivity:	3 VRMS at 30 Hz 1 VRMS at 100 Hz 0.3 VRMS for 1 kHz-20 MHz
Maximum input:	100 V peak 30 Hz-1 kHz 75 V peak 1 kHz-10 MHz 50 V peak 10 MHz-20 MHz
Time base:	1 MHz crystal oscillator

2.2 Test Conditions

Performance specifications apply

1) after correction for test lead zero reading
2) after 10 minute warmup
3) between 15-35° C

2.3 General Specifications

Test frequency:	1kHz for impedance functions
Reading rate:	4 measurements per second
Display:	3-1/2 digit 0.5" (1.2cm) LED, with corresponding annunciator showing units; all decimal points on indicate overrange or illegal condition
Analog outputs:	L, R, C, or G scaled at 0.1V/1000 counts; output impedance: 900 ohms
Digital output:	BCD parallel output representing 3-1/2 digit reading for any quantity
Test terminals:	4-terminal shielded Kelvin test leads, 50 inches (127 cm) long
Operating controls:	push button ON-OFF and function select switches; rotary range select switch
Power requirements:	105-125V or 210-250V; 50-60Hz; 5W
Dimensions:	8.5"Wx9.25"Dx4.44"H (22cmx24cmx12cm)
Weight	6lbs (2.7kg) nominal

2.4 Determination of Complex Impedance Accuracy:

The accuracy of the measurement of the imaginary component of a complex impedance is affected by the amplitude of any associated real component. In other words, the accuracy of capacitance and inductance readings is reduced by the presence of non zero conductance and resistance respectively. See the impedance models above for reference. The amount of error contribution is given in the specifications above as 1% of the G or R readings. This refers to absolute COUNTS of the reading on the SAME RANGE. For example, a 1.0 mH inductor, being measured on Range 2, shows a resistance reading of 12.00 ohms on the same range; the error contribution of the resistance is +/- 12 counts (1% of 1200) added to the inductance COUNTS. Frequently, with low inductors, the resistance reading will be out of range. In the above example, the resistance might be 35.0 ohms viewed on Range 3, would be equivalent to 3500 counts on Range 2, and the error contribution to the inductance seen on Range 2 would now be +/- 35 counts.

Clearly, the effect of this error is more likely to be seen with inductors than with the more ideal capacitors, unless of course an in-circuit measurement is being made.

2.5 Options and Accessories

1) -F Option for Frequency Counter

2) -DO Option for signed 3-1/2 digit BCD output

3) CLC-502 Single Channel Digital Limits Comparator. May be used for impedance OR dissipation or both quantities sequentially; Two comparators may be cascaded for simultaneous (C and D) or (L and D) testing. (Requires DO option).

3.0 OPERATION

3.1 Basic Setup

Connect the IMF-600 to a grounded power source. Operation at either 110 or 220 VAC is possible by selecting internal straps. The proper operating line voltage is indicated underneath the unit along with an abbreviated operating guide.

Press the POWER switch which is a push-on push-release button; the displays will light. To adjust the tilt handle, pull outward on its pivots and set the handle to provide a convenient viewing angle.

3.2 General Procedure

Operation of the IMF-600 is straightforward:

1) Select the desired function with the front panel pushbutton. For voltage or current, select the appropriate position of the "DC/AC true RMS" button.

2) Connect the Kelvin terminals to the unknown component or source. The polarity of the leads has no significance except for dc measurements or the application of a bias voltage.

3) Turn the RANGE knob to obtain the highest "in range" reading, i.e. a number between 200-1999 counts. Overrange or an illegal condition are indicated by all decimal points being lighted.

4) To obtain the dissipation factor for a capacitive or inductive component, press the "D" pushbutton in addition to the "C" or "L" button. If the "D" button is preseed along with any of the other functions, an illegal condition will be indicated. D values greater than 1.999 will show overrange, but may be computed.

The correct measurement is displayed within one second and repetitive measurements are made at the rate of four per second; the decimal point and the unit of measure will be very clearly shown. If all decimal points are on, advance the range until a proper reading is obtained, or detemine if an improper condition exists.

Table 3.1 shows the various display conditions which may occur along with their possible causes.

The impedance functions are protected by internal circuitry and by a fuse on the rear panel. The current function is protected by a diode network and by a fuse accessible by removing the top cover.

3.3 Voltage Measurement

For voltage measurement, the IMF-600 may be used like any digital multimeter. The "V" pushbutton should be depressed, and the "DC/AC" pushbutton should be out or in as desired for dc or ac true RMS measurement respectively. The red lead is the positive terminal, and the black lead is the common or negative terminal.

The shielded leads of the IMF-600 will provide some noise rejection when measuring a voltage across a high impedance.

The voltage function has the five conventional digital multimeter ranges of 200.0 mV, 2.000 V, 200.0V and 1000.V (750.V for AC) which correspond to Range knob settings of 1-5 respectively. Ranges 6 and 7 are repeats of Range 5, i.e. the 1000. V range.

WARNING

OBSERVE ALL SAFETY RULES WHEN MEASURING HIGH VOLTAGES.

BE CAREFUL NOT TO TOUCH THE PROBE TIPS WITH YOUR FINGERS OR ALLOW THE PROBE TIPS TO TOUCH EACH OTHER.

DO NOT CONNECT THE COMMON TERMINAL ON THE REAR PANEL TO EARTH OR OTHER EXTERNAL GROUND WHEN MEASURING A VOLTAGE REFERENCED TO THAT GROUND SUCH AS A LINE VOLTAGE.

THE VOLTAGE ON THE BLACK LEAD APPEARS ON THE COMMON TERMINAL ON THE REAR PANEL FOR THE "V" AND "I" FUNCTIONS.

DO NOT EXCEED THE MAXIMUM LIMITS FOR SAFE OPERATION OF THE INSTRUMENT:

MAXIMUM INPUT VOLTAGE: 1000 VOLTS PEAK
MAXIMUM COMMON MODE VOLTAGE: 500 VOLTS PEAK

Table 3.1. Display Conditions and Causes

CONDITION	CAUSE
1. All decimal points are on	-Overrange; advance range knob; if ranges are exhausted on R, use G; if ranges are exhausted on C, use L (see sections 3.6.3 and 3.7.3).
	-F (Frequency) button is pressed in a unit not having that option
	-D button is pressed along with R, G, F, V, or I button
	-A D (dissipation) value of >1.999 is obtained; D must be computed
2. All decimal points are on-no annunciators	-None of the function buttons are depressed.
3. Negative impedance reading	-A capacitive component (or one effectively capacitive at 1kHz) is being measured with the "L" function.
	-An inductive component (or one effectively inductive at 1kHz) is being measured with the "C" function.
	-A nonlinear component such as a diode is being measured; such a component may require a bias voltage.

3.4 Current Measurement

For current measurement, the IMF-600 may be used like any conventional digital multimeter. The "I" pushbutton should be depressed, and the "DC/AC" pushbutton should be out or in as desired for dc or true RMS ac measurement respectively. The red lead is the positive terminal and the black lead is the common or negative terminal.

Due to the multifunctional nature of this instrument, it is necessary, for current measurement ONLY, that the current carrying leads of the red and black Kelvin terminals be in electrical contact with the current source. For the sake of convenience, it is simpler, in practice to just be certain that BOTH ends of each Kelvin terminal are in contact with the current source.

The current function has the five conventional digital multimeter ranges of 200.0 uA, 2.000 mA, 20.00 mA, 200.0 mA, and 2000. mA which correspond to Range knob settings of 1-5 respectively. Ranges 6 and 7 are repeats of Range 5, i.e. the 2000. mA range.

The current function is protected with a 2 ampere fuse as well as with a diode circuit which prevents the voltage across the current measurement resistors from exceeding about 0.3 volts. The fuse is located on circuit card IMF-5 adjacent to the rotary Range switch, and may be accessed by removing the top cover and the Frequency Counter circuit card if present.

WARNING

INSTRUMENT DAMAGE AND OPERATOR INJURY MAY RESULT IF THE FUSE BLOWS WHILE CURRENT IS BEING MEASURED IN A CIRCUIT WHICH EXHIBITS A OPEN CIRCUIT VOLTAGE GREATER THAN 500 VOLTS.

3.5 AC True RMS Measurement

The IMF-600 measures the true RMS (root mean square) value of a signal which is defined as:

$$Xrms = \sqrt{\overline{X^2}}$$

where X is the mean or time average value of the signal X(t). The RMS value is therefore indicative of the power contained in a signal. In particular, the RMS value of an ac current or voltage is defined as being numerically equal to the dc current

or voltage that produces the same heating effect in a given resistance that the ac current or voltage produces.

The older methods of ac measurement are usually signal averaging techniques, i.e. they provide the value $\overline{|X|}$, the average or dc value of the rectified signal. The two types of meters are usually calibrated to correspond only for a pure sine wave.

The RMS feature allows accurate measurement of common waveforms like distorted or mixed frequency sine waves, sawtooths, noise, pulse trains (with a duty cycle of at least 10%), etc. Voltage readings from ordinary average responding ac meters can be incorrect or misleading. Table 3.2 gives the conversion information for a number of common waveforms.

To measure a signal containing both ac and dc components, first measure the RMS value of the ac component using the ac function of the meter. Then measure the dc component using the dc function of the instrument. The relationship between the total RMS value of the waveform and the ac and dc components is:

$$\text{RMStotal} = \sqrt{(\text{ac comp RMS})^2 + (\text{dc comp})^2}$$

3.6 Resistance and Conductance Measurement

3.6.1 1kHz Resistance and Conductance Measurement Considerations

In most cases, measurent of resistance or conductance (1/resistance) with the IMF-600 is equivalent to the measurement with an ordinary ohmeter, and the resulting reading will be the same. Note, however, that the IMF-600 measures resistance at 1kHz, wheras an ohmeter determines resistance at dc. For virtually all resistors, the result is identical, but care has to be taken when measuring complex components such as high value wire-wound resistors or multiple components such as a resistor-capacitor combination as shown in Figure 3.1.

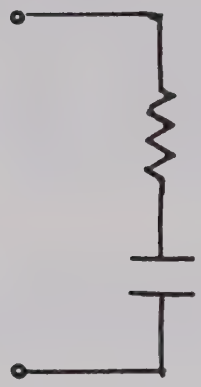
3.6.2 Conductance Measurement

Conductance can be considered as either a new type of measurement or another way to measure resistance, and in particular high resistance (Section 3.6.3). Conductance measurements are made by using the "G" function. The display is in conductance units, siemens (formerly known as mhos), where

$$G(\text{in siemens}) = 1/R(\text{in ohms}).$$

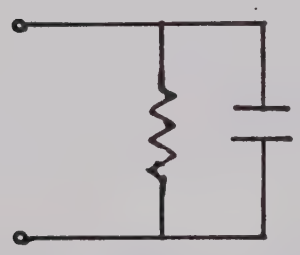
Table 3.2. RMS and Average Responding Meter Conversions

WAVEFORM	CALIBRATED AVERAGE RESPONDING METER	RMS METER
Sine	1.000	1.000
Square	1.110	1.000
Triangle	0.960	1.000
Full wave rectified sine	0.421	0.435
Pulse (D=fractional duty cycle)	$2.22\sqrt{D-D^2}$	$2\sqrt{D-D^2}$



Ohmeter reading: open circuit.

IMF-600 reading: finite.



Ohmeter reading: correct.

IMF-600 reading: correct, as long as "C" reading is not overrange. Range may be advanced in such a case. "G" and not "R" should be used for best accuracy.

Figure 3.1 Resistance Measurements of Resistor-Capacitor Combinations

As a conductance meter, the IMF-600 can directly measure inverse-function components. For example, the resistance of a photodiode decreases as the available light increases; conductance and light level, therefore, increase or decrease together allowing easier, less error prone, testing. The same is true for a number of other variable resistance transducers. It is also sometimes easier, in circuit computations, to multiply by conductance than to divide by resistance.

3.6.3 High Resistance Measurement

In the resistance function, maximum measurement capability is 2 megohms. For resistances from 1999 kilohms to 1000 megohms, use Range 1 (2.000 uS) of the G (conductance) function where G=1/R. Except for high voltage stress testing, this range can replace a megger for a number of applications. It can be used to check high value resistors and non-capacitive low leakage components.

High resistors should be guarded or shielded, if possible, by connecting the shield to earth ground or to the COMMON terminal on the rear panel of the meter.

3.6.4 Low Resistance Measurement

The IMF-600 is capable of measuring low resistance with a resolution of .001 ohm. The resistance of wires, connectors, or contacts can therefore be determined. The four-terminal Kelvin leads allow accurate low impedance measurement by eliminating contact resistance. This is accomplished by having the test current applied through the unknown by one pair of leads and measuring the voltage across it with the second pair. See Section 1.3.

Certain care does have to be taken in making low impedance measurements. The Kelvin leads should be clean and should grip firmly and consistently, because a change in the location of the point on the lead of the unknown being gripped may produce a significant change in the resistance.

3.7 Capacitance Measurement

3.7.1 General Procedure

Measurement of capacitance is straightforward; simply press the "C" pushbutton and select the range providing the maximum resolution. Capacitance may be resolved to 0.1 pF, and values as high as 20,000 uF may be measured.

The capacitance model assumed by the IMF-600 is the parallel capacitor conductor (or resistor) combination as shown in Figure 3.2a, where Cp and Gp are the parallel equivalent capacitance and conductance respectively. For an ideal capacitor, coductance Gp is zero (infinite resistance). For a real capacitor, Gp represents the leakage or the various other loss elements. Most non-electrolytic capacitors are virtually ideal. For an in-circuit capacitor, Gp represents the conductance of the circuit across the unknown capacitor.

The IMF-600 will measure both Cp and Gp simultaneously and will display one or the other as buttons "C" or "G" are pressed. The dissipation factor

$$D=Gp/2\pi fCp$$

where f is the frequency (1000 in this case) is provided whenever the "D" button is pressed. The range chosen should be for best capacitance, not conductance, resolution.

In-circuit capacitance may be measured as long as the conductance does not overwhelm the capacitance, i.e. as long as the conductance counts displayed are not much greater than the capacitance counts.

An alternative capacitor model is the series type shown in Figure 3.2b where Cs and Rs are the series equivalent capacitance and resistance respectively. The relationship between the two models is:

$$Cs=(1+D^2)Cp.$$

$$Rs=D^2/(1+D^2)Gp$$

3.7.2 Low Capacitance Measurement

When measuring small capacitors, particularly on the lowest capacitance range (200.0pF), two potential problems should be carefully avoided.

First, due to their high impedance, small capacitors should be shielded or guarded to earth ground or to the COMMON terminal on the rear panel. A metal case or a piece of foil connected to that terminal may be used.

Second, cable or stray capacitance can affect the measurement. Always maintain the physical orientation and position of the test leads during a test, since the capacitance reading may change by as much as a few picofarads as the lead separation or relative orientation is changed. Note that

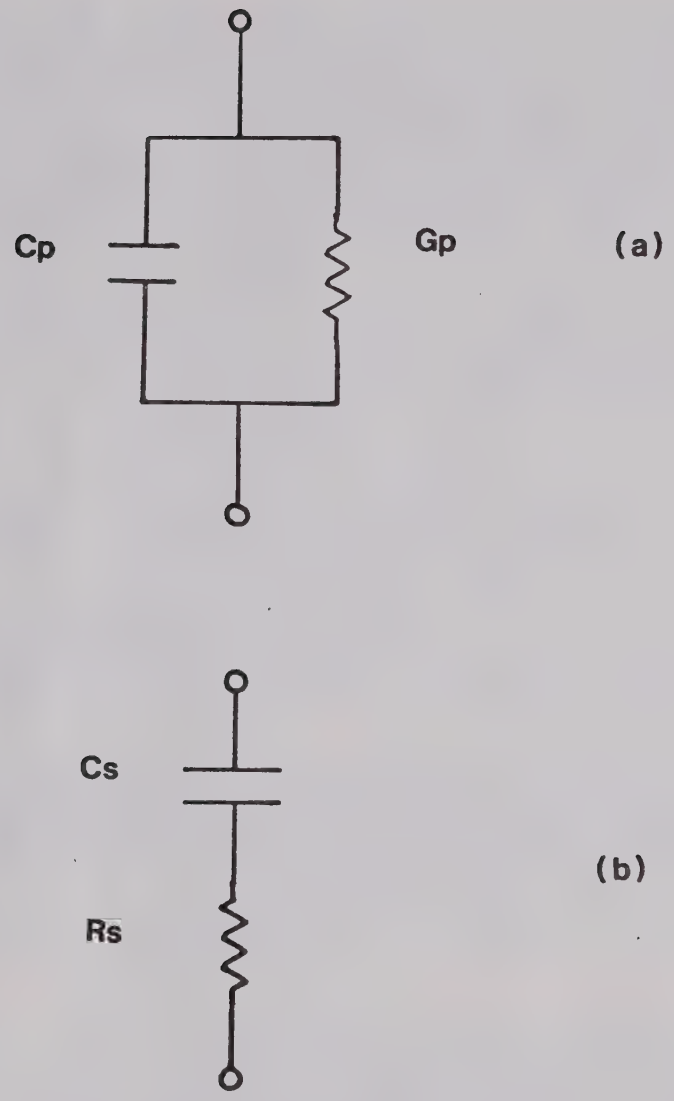


Figure 3.2 Capacitance Models

although the Kelvin leads are shielded, the tips are not and do present a capacitance between them. This residual capacitance must be kept constant, and may be either arithmetically subtracted from the reading or may be zeroed out by the ZERO C1 (or C2 for the second capacitance range) trimming potentiometer accessible from the rear panel.

For the most sensitive range C1 (200.0pF), a gain potentiometer (C1G) is also accessible from the rear panel.

All four conductors of the Kelvin leads are not required for low capacitance (or other high impedances), since the currents employed are small. The leads may therefore be lengthened with a pair of single conductors, as long as they are shielded, or the capacitance they contribute is taken into consideration.

3.7.3 High Capacitance (>200 uF) Measurement

The IMF-600 is a versatile instrument that allows measurement beyond the C7 range limit of 200 uF. High capacitors may be measured on the inductance function using the following conversion:

$$Cs=-1/(2\pi f)^2 Ls= -2.533 \times 10^{-8}/Ls$$

where f=frequency in hertz (1000 in this case), Ls=series inductance in henries, and Cs=series capacitance in farads. Note that meter will display a negative reading. As an example, a 330 uF capacitor will read 76.7 uH. Note, however,that this is the series, not the parallel, equivalent capacitance.

3.8 Inductance Measurement

3.8.1 General Procedure

Measurement of inductance is straightforward; simply press the "L" pushbutton and select the range providing the maximum resolution. Inductance may be resolved to 0.1 uH, and values as high as 200 H may be measured.

The inductance model assumed by the IMF-600 logic is the series inductor-resistor combination shown in Figure 3.3a where Ls and Rs are the series equivalent inductance and resistance. For a real inductor, Rs represents the resistance of the conductor as well as the various other loss elements. Unlike capacitors which are often virtually ideal, inductors will have considerable finite resistance.

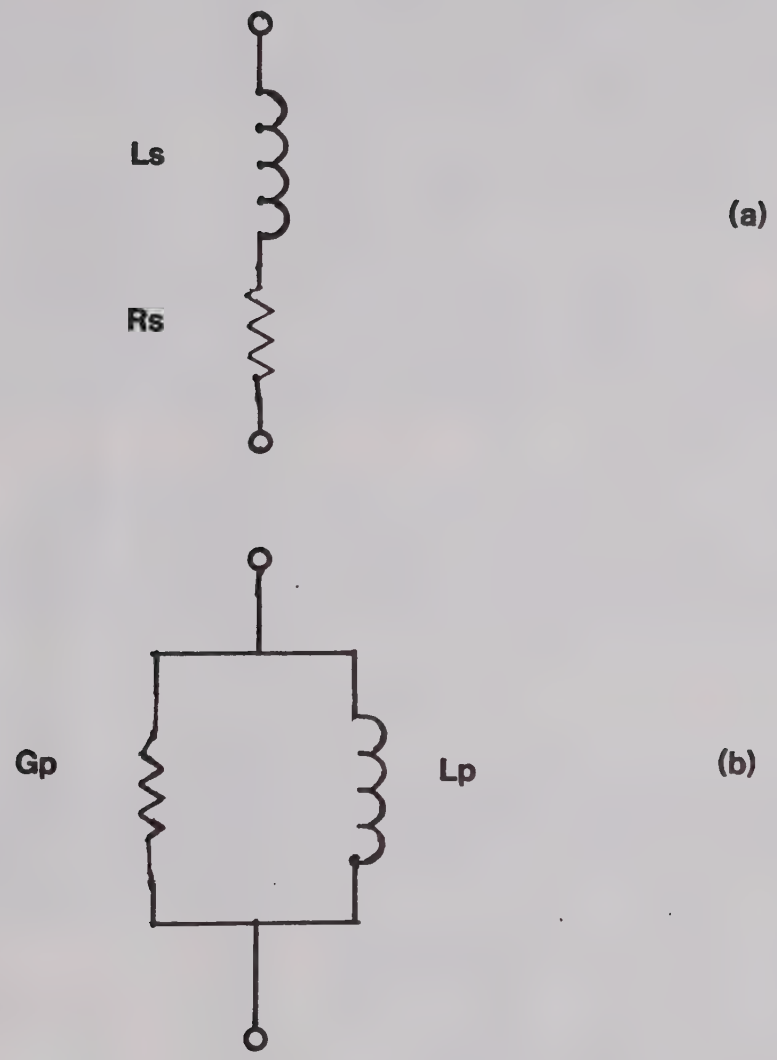


Figure 3.3 Inductance Models

The IMF-600 will measure both Ls and Rs simultaneously and will display one or the other as buttons "L" or "R" are pressed. The quality factor Q is available as the reciprocal of the dissipation factor D, i.e. Q=1/D. They are defined as follows:

$$1/Q=D=2\pi fLs/Rs$$

where f=frequency in hertz (1000 in this case). The value for D is provided whenever the "D" pushbutton is pressed.

The range chosen should be for best inductance, not resistance, resolution. Because a series inductance model is employed, in-circuit inductors may be measured only as long as the impedance across them is high.

An alternative inductance model is the parallel type shown in Figure 3.3b where Lp and Rp are the parallel equivalent inductance and resistance respectively. The relationship between the two models is:

$$Lp=(1+D^2)Ls$$

$$Gp=1/(1+Q^2)Rs$$

3.8.2 High Inductance Measurement

As in the case of low capacitance or high resistance, ac pickup should be avoided. The leads should be as short and direct as possible. The inductor under test may be shielded to earth ground or to the the COMMON terminal on the rear panel, and hands should be kept away. Stray capacitance will be minimized by following these steps. Additionally, care should be taken to avoid any external magnetic fields.

3.8.3 Low Inductance Measurement

leads of the inductance under test may contribute some impedance on sensitive ranges. Closely spaced twisted leads will minimize inductance and pickup. The inductance of the Kelvin leads may be determined by shorting them together and either arithmetically subtracting the residual reading or eliminating it. This may be done with the ZERO L1 and L2 potentiometers accessible from the rear panel for inductance Ranges 1 and 2 respectively.

For the most sensitive inductance range L1 (200.0uH), a gain potentiometer (L1G) is also accessible from the rear panel.

3.8.4 Mutual Inductance Measurement

The self and mutual inductances of a pair of coupled coils is given as follows:

$$V1=L1\,dI1/dt + M\,dI2/dt$$

$$V2=M\,dI1/dt + L2\,dI2/dt$$

where V, I, and L are the voltages currents and self inductances of the two coils, and M is the mutual inductance. M may be computed as follows:

1) With coil 2 open circuited, determine L1 for coil 1 using the IMF in the normal fashion.

2) With coil 1 open circuited, determine L2 for coil 2 using the IMF in the normal fashion.

3) With coil 2 short circuited, use the IMF to determine the Llsc inductance of coil 1.

4) Using the above relationships, the mutual inductance may be computed as follows:

$$M=\sqrt{L2(L1-Llsc)}$$

3.9 Determination of the Dissipation Factor (D) of Capacitors

The dissipation factor D of a capacitor is defined as

$$D=Gp/2\pi fCp$$

where Cp=the parallel equivalent capacitance, Gp=the parallel equivalent conductance, and f=frequency in hertz (1000 in this case). Clearly, D is zero for an ideal capacitor and high for a poor one.

D values up to 1.999 may be displayed by pressing the "D" pushbutton while the "C" pushbutton is depressed. The "D" pushbutton is a momentary switch. The lighted "D" annunciator is diplayed along with the capacitance unit.

D values greater than 1.999 may be directly computed from the above relationship, or more simply by:

$$D=1.592\ Gcount/Ccount$$

where Gcount and Ccount are the displayed G and C counts on the same range, without decimal points. The range providing the

maximum capcitance, not conductance, resolution must be used.

The "D" pushbutton, when pressed, will cause all decimal points to go on except when the "C" or "L" pushbuttons are selected.

If the dissipation value is desired as an output, the digital output option provides whatever quantity is displayed.

3.10 Determination of the Quality Factor (Q) of Inductors

The quality factor (Q) of an inductor is defined as:

$$Q=2\pi fLs/Rs$$

where f=frequency in hertz (1000 in this case), Ls= series equivalent inductance, and Rs=series equivalent resistsnce. Clearly, Q is infinite for an ideal inductor and low for a poor one.

The IMF-600 computes the dissipation factor D=1/Q, which may be displayed by pressing the "D" pushbutton while the "L" pushbutton is depressed. The "D" pushbutton is a momentary switch. Q may then be computed as the reciprocal of D; this may be done so long as Q>0.5 (or D<2). For Q<0.5, the value may be directly computed from the above raelationship, or more simply by:

$$Q=Lcount/1.592\ Rcount$$

where Lcount and Rcount are the displayed L and R counts on the same range without decimal points. Whenever possible, the range providing the maximum inductance, not resistance resolution must be used.

When the "D" pushbutton is pressed, the lighted "D" annunciator is displayed along with the inductance unit.

The "D" pushbutton, when pressed, causes all decimal points to go on except when the "C" or "L" pushbuttons are selected.

If the dissipation value is desired as an output, the digital output option provides whatever quantity is displayed.

3.11 Application of a DC Bias Voltage Across a Capacitor

Although ideal capacitors have a constant capacitance independent of the voltage across them, many electrolytic ones

and other capacitive devices do not. The IMF-600 allows for the application of of a dc voltage of up to 100 volts across the capacitor under test.

For safety of the operator, it is recommended that external bias be limited to a maximum of 30 V. If necessary, with proper precautions to safeguard from the danger of electric shock, higher voltages may be used.

In order to apply a bias voltage, connect an external dc voltage source as shown in Figure 3.4a If the capacitance is high and contact resistance is significant, follow Figure 3.4b. Separate the red V+ and I+ leads and connect the V+ lead as directly to the capacitor as possible and apply the bias voltage between the I+ terminal and the capacitor as shown.

Shield or ground the capacitor if called for, as long as the shield is insulated from the two main terminals of the capacitor.

In order for the external supply to be able to provide the required bias without introducing measurement error, it must meet these requirements:

1. Supply the required dc bias voltage.
2. Provide the charging current.
3. Serve as source and sink for the measuring ac current which equals 2000 CVtest, where Vtest=1.4 VRMS for Ranges 1-6, and 0.14 VRMS for Range 7.
4. Appear as a low impedance, at 1 kHz, in comparision to the capacitor under test.

In order to make a power supply or battery suitable for this purpose, connect, across it, a bleeder resistor to act as a current sink, and a large capacitance (many times larger than the full scale value being used) to reduce its apparent impedance.

Note that that the the applied bias voltage does not completely develop across the capacitance under test. A small portion is taken up by the internal coupling capacitors. If the bias voltage must be precisely known, it should be measured across the capacitor, but not during the actual measurement.

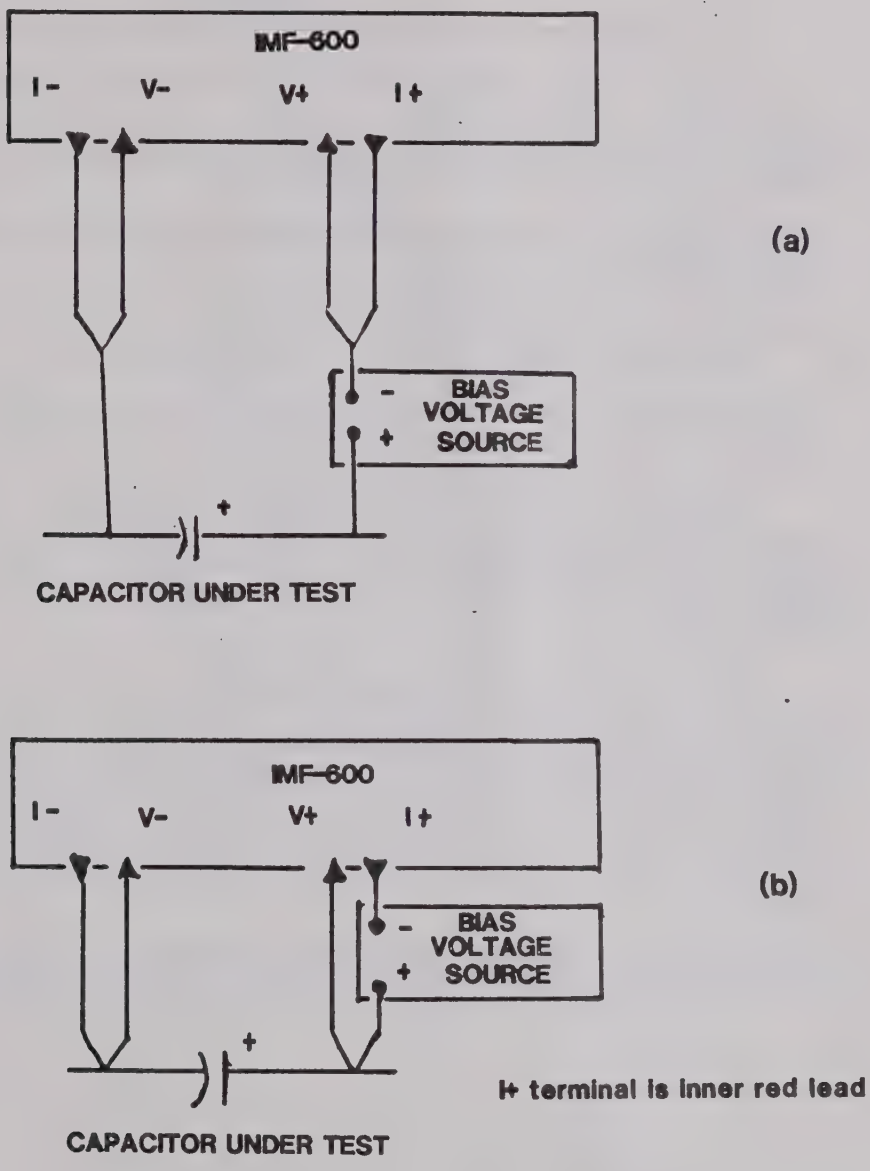


Figure 3.4 Applying a DC Bias Voltage Across a Capacitor

WARNING

TO MINIMIZE THE DANGER OF ELECTRIC SHOCK, LIMIT BIAS TO 30 V.

BIAS VOLTAGE IS PRESENT AT KELVIN LEADS AND ON THE CAPACITOR UNDER TEST.

WHEN HIGH BIAS VOLTAGES ARE USED, DO NOT LEAVE THE INSTRUMENT UNATTENDED.

CAPACITORS REMAIN CHARGED AFTER TEST. DISCHARGE CAREFULLY.

3.12 Application of a DC Bias Current Through an Inductor

Although ideal inductors have a constant inductance independent of the current through them, many real ones, especially those with saturating cores, do not. The IMF-600 permits the application of a dc current through the inductor under test.

To apply such a current, connect an external dc current source as shown in Figure 3.5. It is necessary that the impedance of the current source, or the entire circuit in parallel with the inductor under test, be sufficiently high in comparison with the impedance of the inductor at 1kHz. Or, the impedance of the current circuit may be determined separately, with the IMF-600, and its effect on the inductance measurement computed.

Shield or ground the inductor if called for, as long as the shield is insulated from the two main terminals of the inductor.

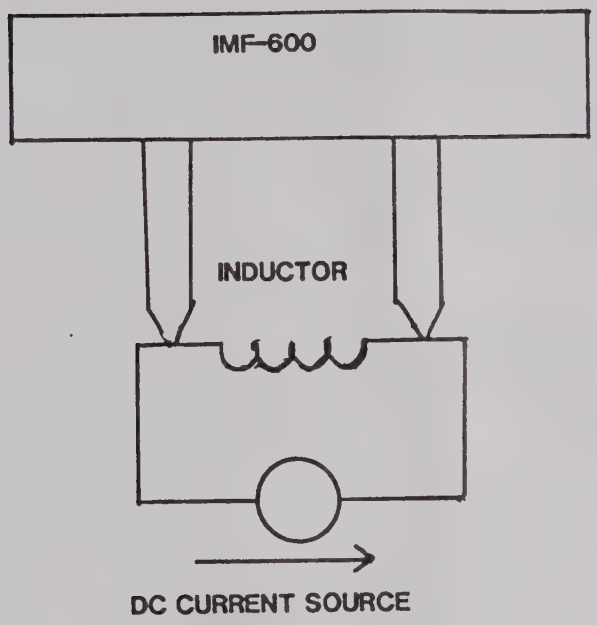


Figure 3.5 Applying a DC Bias Current through an Inductor

4.0 FREQUENCY COUNTER (OPTIONAL)

4.1 General Procedure

The use of the IMF-600 for frequency measurements is straightforward. All that is required is to press the "F" pushbutton and to select the range providing the maximum resolution. Units not having the frequency counter option will display overrange, i.e. all decimal points will be on.

The frequency function has 6 ranges of 200.0 Hz, 2.000 kHz, 20.00 kHz, 200.0 kHz, 2.000 MHz, and 15.00 MHz which correspond to Range knob settings of 1-6 respectively. Range 7 is a repeat of Range 6, i.e. the 15.00 MHz range.

The nominal display will provide a 3-1/2 digit reading, but the internal frequency computation is made to 4-1/2 digits. This additional significant figure may be viewed by downranging and reading the two least significant digits to replace the single least significant digit of the original range. If, for example a reading of 18.53 kHz is seen on Range 3, going to Range 2 may give the reading X.5.2.7. where X indicates a meaningless digit and the decimal points show overrange. The resultant 4-1/2 digit reading, in this example, is 18.527 kHz. This is also a more reliable measure since it is obtained over a ten times longer gating period. Clearly this procedure cannot be applied for Range 1 (200.0 Hz).

4.2 Notes on Reliable Frequency Measurement

There are a number of important considerations in taking reliable readings. These are based on knowing the signal source characteristics, the counter input characteristics, and the coupling between the two.

The IMF-600 has a high sensitivity, and if the signal source is basically noisy, the count may be quite meaningless. It is important that the signal to noise ratio be as high as possible; a ratio of one hundred to one may be needed to obtain stable measurements. The stability of the input signal source, or lack of it, may also cause noise or variation in the reading. In some cases, especially for relatively low frequencies, a small bypass capacitor may be used to clean up the input signal.

It is sometimes helpful under noisy or high frequency conditions to use a separate grounding lead from the black

Kelvin test lead to the COMMON terminal on the rear panel.

It is important to be aware that the the test leads will appear as approximately 100 pF of capacitance. Any additional external cables will also contribute to such a loading. Where practical these should be kept as short as possible. Nevertheless, the cable may load down or detune high impedance signal sources.

If high level high frequency signals cause unstable frequency readings or display segment flicker, the input should be attenuated if possible.

5.0 SYSTEM OUTPUTS

5.1 Analog Outputs

The capacitance, inductance, resistance, or conductance quantity being displayed by the IMF-600 will appear as an analog voltage, scaled at 0.1 volt/1000 counts, at the rear panel jack. The output has an impedance of 900 ohms and may be observed with respect to the COMMON terminal.

The dissipation value is available as a digital output with the the digital output option. Consult IET Labs if an analog output for dissipation is required.

In the IMF-600, processing occurs in analog form, and the quantity being determined is computed as an analog voltage which is fed to a 0.2 volt, 2000 count, analog to digital converter. Although this converter cannot handle signals greater than 0.2 volts, such "overrange" signals are still brought out to the back panel, and may be correct even while the display indicates overrange. Such outputs (>0.2 volts) must be used WITH CAUTION, because the upper legal limit is not the the same for all ranges or functions, but they may be useful in many cases.

WARNING

THE COMMOM TERMINAL ON THE REAR PANEL IS CONNECTED TO THE BLACK KELVIN LEAD FOR THE VOLTAGE AND CURRENT FUNCTIONS AND SHOULD GENERALLY NOT BE USED IN THOSE FUNCTIONS.

5.2 Digital Outputs (Optional)

Units with a "DO" option provide a connector on the rear panel with a signed BCD representation of the displayed value on any selected function. This output is the BCD equivalent of the analog to digital converter output. When the "D" button is pressed, the dissipation becomes the digital value being output.

The digital outputs may be used with the IET Labs Model CLC-502 Digital Limits Comparator for upper and lower limits selection. These comparators may be cascaded for dissipation value testing or for bin sorting.

The digital output pin assignments are given below in Table 5.1. The digital output connector is a 26 pin header on the rear panel. It may be accessed with a "3M Company Model 3399", "GTE Sylvania Inc. Model 6BAxx-26-1xx-xx", "T&B/Ansley Corp.

Table 5.1 Digital Output Connector Pin Assignments

PIN NO.	FUNCTION
1	+5 V
2	Ground
3	10 bit
4	20 bit
5	Sign bit, true (high) for negative and false (low) for positive
6	No connection
7	No connection
8	No connection
9	No connection
10	No connection
11	No connection
12	No connection
13	No connection
14	Overrange bit, true (high) during overrange condition
15	Strobe pulse; see Figure 5.1.
16	40 bit
17	4 bit
18	1 bit
19	2 bit
20	200 bit
21	400 bit
22	800 bit
23	80 bit
24	1000 bit
25	8 bit
26	100 bit

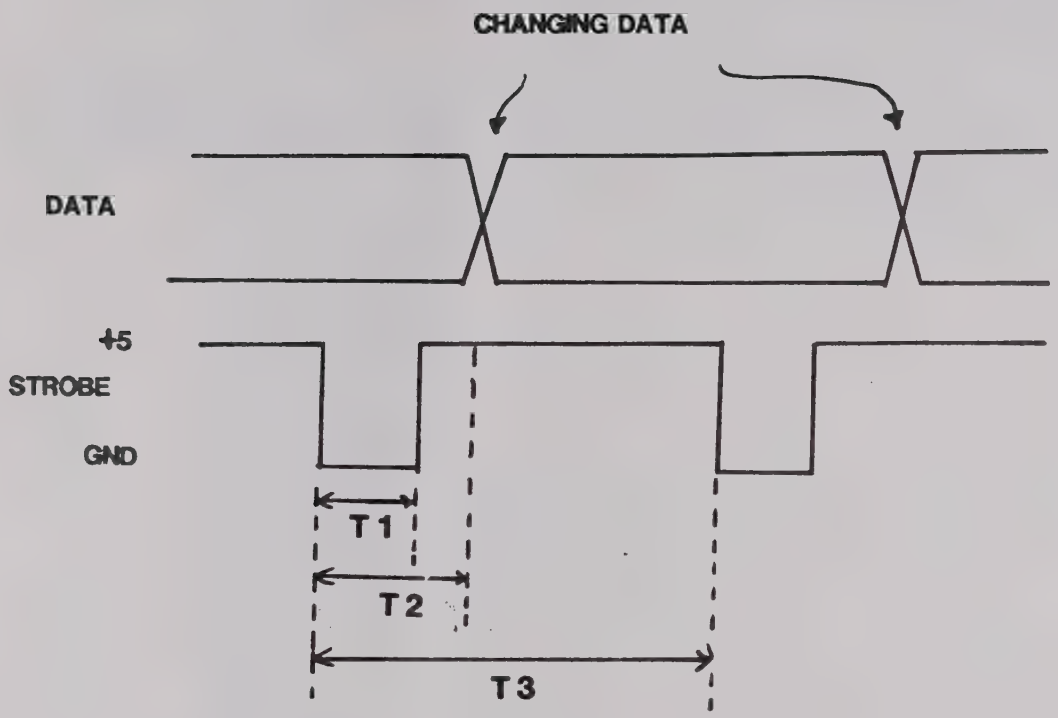
Connector Pin Numbering

13	12	11	10	9	8	7	6	5	4	3	2	1
26	25	24	23	22	21	20	19	18	17	16	15	14

(Viewed Straight on)

Model 609-2600M", or equivalent socket connector. The rear panel connector pin numbering, as the connector is viewed straight on, is also shown in Table 5.1.

The output level is 5 volt positive true logic, capable of driving CMOS or TTL loads. A strobe, an overrange indicator, and +5 volts are also brought out. The strobe timing waveform is shown in Figure 5.1.



	Frequency Counter	All Other Functions
T1	30 us	90 ms
T2	10 us	110 ms
T3	See "Sampling Period", Section 2.2	250 ms

Figure 5.1 Output Strobe Timing

6.0 CALIBRATION

The IMF-600 should be calibrated every six months or if incorrect readings are suspected. Since this instrument measures so many quantities, the calibration procedure is lengthy and requires a number of calibration standards or meters. The procedure is arranged, however, so as to allow bypassing items for which accuracy is not of interest.

Calibration may also be provided by the IET Labs for a nominal charge.

6.1 Disassembly Procedure

Remove the four screws on the bottom of the unit. Carefully remove the top cover.

WARNING

ALTHOUGH NO HIGH VOLTAGES EXIST ON THE UPPER CIRCUIT BOARD, DANGEROUS VOLTAGES DO EXIST INSIDE THE INSTRUMENT. OBSERVE ALL APPLICABLE SAFETY PRECAUTIONS.

If the IMF-600 has a frequency option, the top printed circuit board, IMF-4, must be removed by unscrewing the four nuts holding it in place. It may then be laid over the side of the unit, still connected with its various cables. It is not needed for any calibration procedure.

All calibration steps are performed on circuit board IMF-5, the rotary range switch board, and on IMF-1 the circuit board below it with the pushbutton switches. In the instructions to follow, the prefixes (5) and (1) will refer to the two circuit boards respectively, e.g. 1-T6 indicates trimmer potentiometer 6 on card IMF-1.

Refer to Figures 6.1 and 6.2 for the location of the various adjustments and test points. In the following sections, steps marked (NR) are not required if the quantity in question is not needed or the calibration equipment is not available. They may be bypassed without affecting subsequent steps.

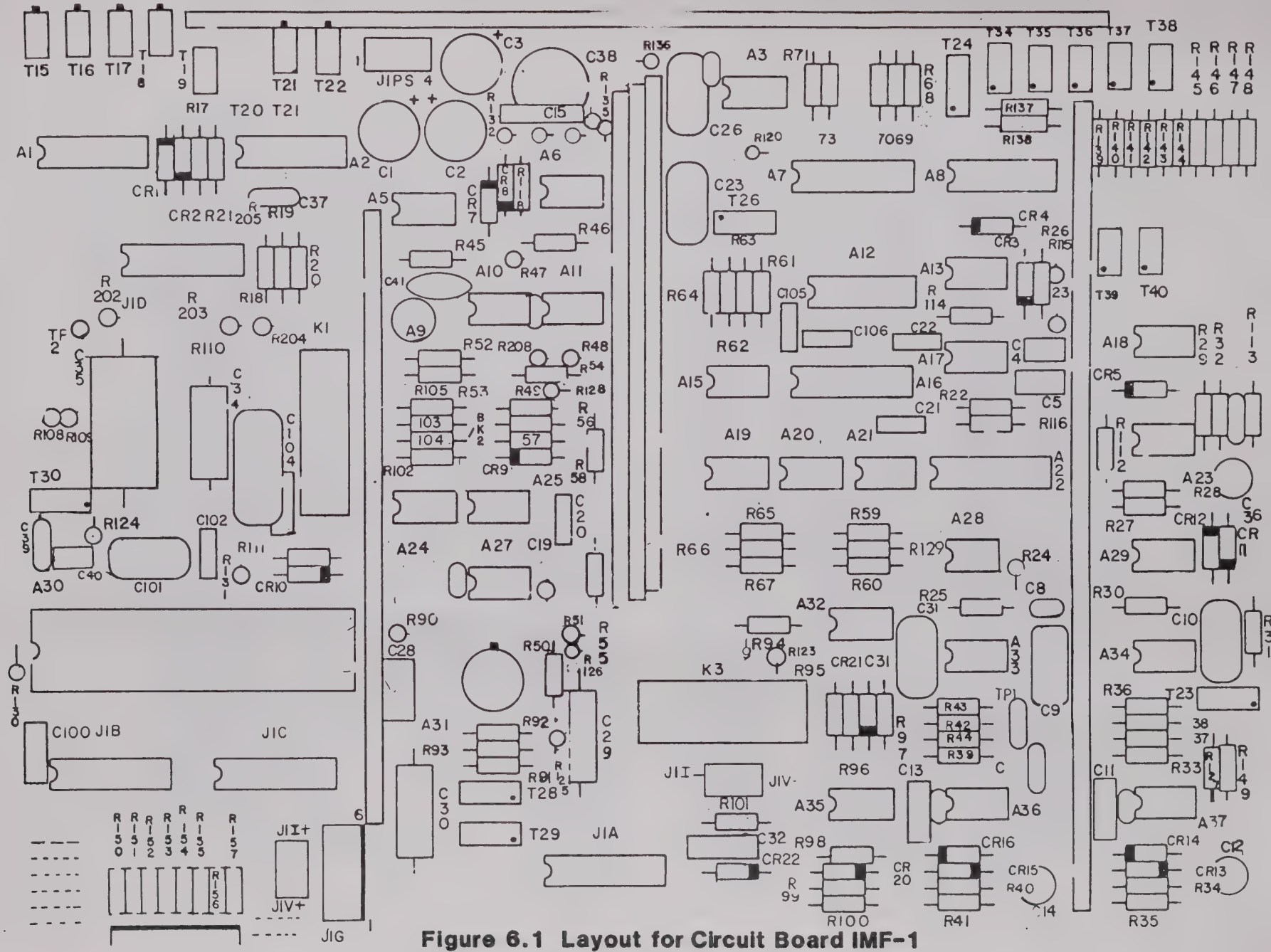


Figure 6.1 Layout for Circuit Board IMF-1

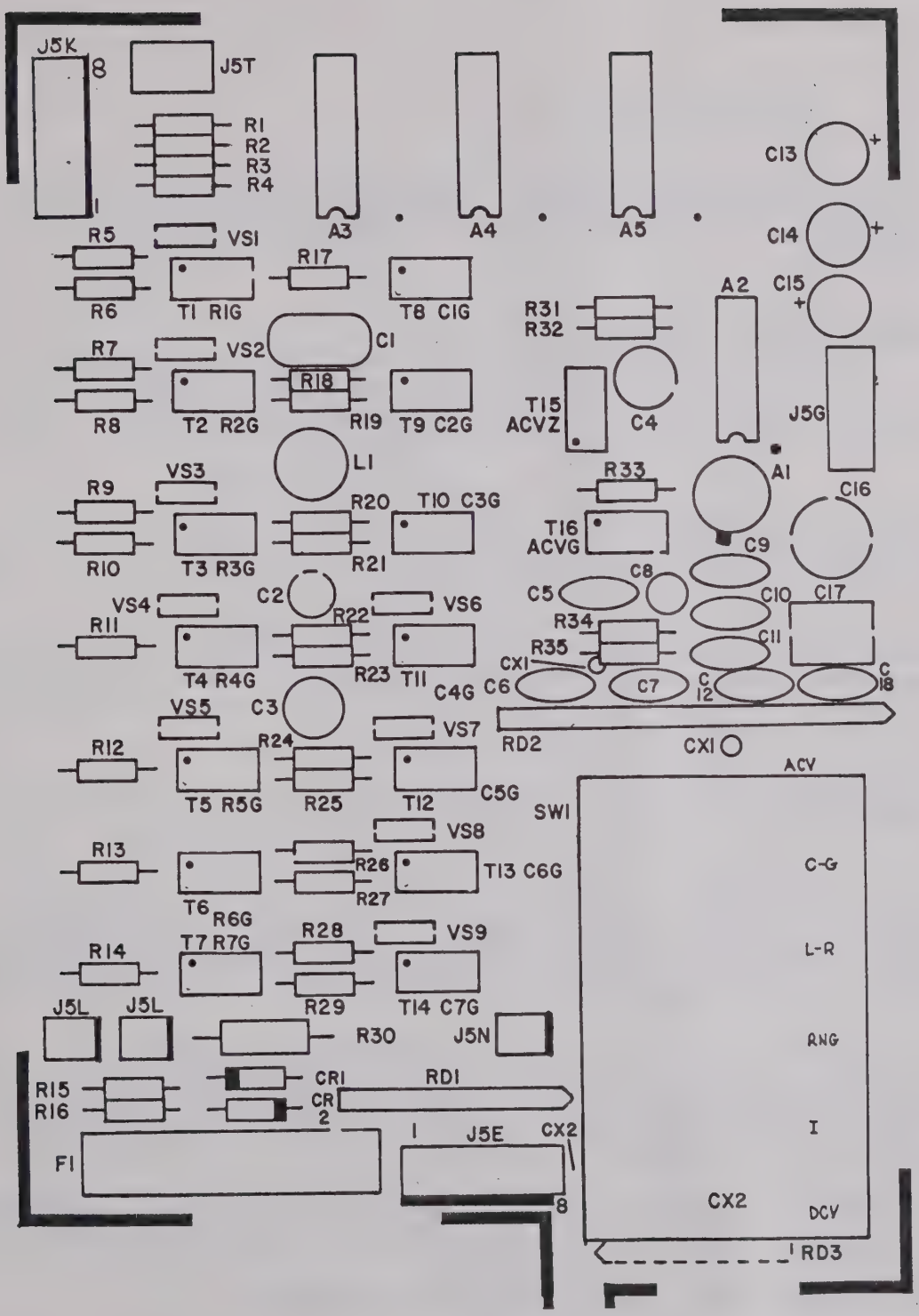


Figure 6.2 Layout for Circuit Board IMF-5

6.2 Calibration Steps

Turn on the IMF-600, cover the top with a flat object and allow it to warm up for 15-20 minutes. For best results, keep it covered when not being accessed in all the following procedure.

6.2.1 Power Supply Check

Use a voltmeter to check the three power supplies at the 1-J1PS connector. Use the rear panel COMMON terminal for the voltmeter low input. The voltages, starting from the left (looking from the front of the unit) are:

+12V, +5V, GND, -12V (within 10%)

6.2.2 DC Voltage Calibration

1. Set the unit on DCV Range 1.

2. Use a 4-1/2 digit voltmeter or a voltage standard to calibrate the 200.0 mV range with a source producing over 1900 counts. Adjust trimmer 1-T30 to obtain a correct reading.

6.2.3 AC Voltage Calibration (NR)

1. Set the unit on AC RMS V Range 1. Short the test leads together.

2. Adjust trimmer 5-T15 for a reading of .000

3. Using either a 4-1/2 digit ac voltmeter (conventional or RMS) or a standard ac voltage source, apply a 100 Hz sinusoidal voltage of .19-.2 V across the test leads. Adjust trimmer 5-T16 for a correct reading.

4. Trim AC Range 2 (2.000V) high frequency response. Using an ac voltmeter (conventional or RMS) or a standard source, apply a 20kHz 1.9-2 volt sinusoidal signal, and adjust trimmer capacitor 5-C17 for a correct reading. It is best to use a non-metallic tool.

5. Trim the AC RMS Range 3 (20.00V) high frequency response as in step 4, using 19-20V, and adjusting trimmer capacitor 5-C16 .

6. Repeat step 4, and readjust if necessary.

6.2.4 AC Current Calibration (NR)

1. Set the unit on AC RMS I Range 1. Keep the test leads apart.

2. Adjust trimmer 1-T29 for a reading of 00.0

3. Using either a 4-1/2 digit as ammeter (conventional or RMS) or a standard ac current source, apply a 100 Hz sinusoidal current of 190-200 uA through the test leads. Adjust trimmer 1-T28 for acorrect reading.

6.2.5 Balance

1. Set the unit on R Range 1.

2. Short the test leads together and adjust trimmer 1-T23 to obtain a reading of .000

6.2.6 Basic Impedance Calibration

1. Set the unit on R Range 4. Measure a standard resistance (or use a calibrated meter) to obtain a reading over 1900 counts. Adjust trimmer 5-T4 to obtain a correct reading.

2. (NR) Set the unit on L Range 4. Measure a standard inductance (or use a calibrated meter) to obtain a reading of over 1900 counts. Adjust trimmer 1-T26 to obtain a correct reading.

3. Set the unit on C Range 4. Measure a calibrated capacitance (or use a calibrated meter) to obtain a reading of over 1900 counts. Adjust trimmer 5-T11 to obtain a correct reading.

4. (NR) Set the unit on G Range 4. Measure a standard conductance (or use a calibrated meter) to obtain a reading of over 1900 counts. Conductance=1/resistance, and a resistance of 505 ohms, for example, has a conductance of 1.980 millisiemens. Adjust trimmer 1-T24 to obtain a correct reading.

6.2.7 Resistance Calibration

Using standard resistors, or a calibrated meter, calibrate the remaining resistance ranges with the indicated trimmers. Use as high a count as possible on each range for best accuracy:

Resistance Range	Nominal Resistance value	Trimmer
1	1.9+ ohms	5-T1
2	19+ ohms	5-T2
3	190+ ohms	5-T3
5	19+ kilohms	5-T5
6	190+ kilohms	5-T6
7	1.9+ megohms	5-T7

6.2.8 Low Conductance Calibration (NR)

1. Set the unit on G Range 1.

2. Measure a standard conductace (or use a calibrated meter) to obtain a reading of over 1900 counts. A resistance of slightly over 500 kilohms is suitable. Conductance=1/resistance. Adjust trimmer 5-T8 to obtain a correct reading.

6.2.9 Capacitance Calibration (NR)

1. Set the unit on C Range 1.

2. Place the test leads apart at a separation comparable to to the size of a capacitor. Keeping hands away, use the C1 ZERO potentiometer (1-T15), accessible from the rear panel, to obtain a reading of .000

3. Repeat step 2 for C Range 2 using the C2 ZERO adjust (1-T16).

4. Using standard capacitors (or a calibrated meter), calibrate the following capacitance ranges with the indicated trimmers. Obtain as high a count as possible for best accuracy:

Capacitance Range	Nominal Capacitance value	Trimmer
C1	190+ pF Rear panel (C1G)	1-T21
C2	1.9+ nF	5-T9
C3	19+ nF	5-T10
C5	1.9+ uF	5-T12
C6	19+ uF	5-T13
C7	100+ uF	5-T14

6.2.10 Low Inductance Calibration (NR)

1. Set the unit on L Range 1.

2. Short the test leads together. Use the L1 ZERO adjust, (1-T17), accessible from the rear panel, to obtain a reading of 0.00

3. Repeat step 2 for L Range 2 using the L2 ZERO adjust (1-T18).

4. Set the unit on L Range 1.

5. Measure a standard inductance (or use a calibrated meter) to obtain as high a reading as possible on this 200.0 uH scale. Adjust trimmer 1-T22 (L1 Gain), accessible from the rear panel,

to obtain a correct reading.

6.2.11 Dissipation Factor Calibration (NR)

6.2.11.1 Capacitance Dissipation calibration

1. Set the unit on C Range 4.

2. Set a decade capacitor to obtain areading of 159.2nF. Connect a 1000 ohm standard resistor across the capacitor. Adjust trimmer 1-T37 for a D reading of 1.000 when the "D" button is pressed. Other capacitance or resistance values may be used, and the resulting D may be computed by the relation:

D=1.592 Gcounts/Ccounts

6.2.11.2 Inductance Dissipation Calibration

1. Set the unit on L Range 4.

2. Connect the leads to an inductor of between 100-200mH in series with a 1000 ohm resistor. Observe the resistance and inductance readings. Compute the dissipation by the following:

D=1.592 Rcounts/Lcounts

3. Adjust trimmer 1-T38 to obtain the computed D value when the "D" button is pressed.

6.2.11.3 Low Capacitance Dissipation Adjustment

1. Set the unit on C Range 1.

2. Using a non lossy capacitor, such as mica, between 100-200pF, measure its conductance with the "G" button and set it to zero with 1-T39.

6.2.12 Complex Impedance Adjustment

1. Set the unit on C Range 2.

2. Use a capacitor around 1000pF, and obtain a measurement. Place 100 kilohms across it and set 1-T40 for zero change in the capacitance reading.

3. Set the unit on C Range 4.

4. Repeat step 2 with a 0.1uF capacitor, a 1 kilohm resistor, and 1-T34.

5 Set the unit on L Range 3.

6. Measure an inductor around 10mH with and without 100 ohms in series. Adjust 1-T35 for zero change in the inductance reading.

7.0 CIRCUIT DESCRIPTION

7.1 Basic Functional Description

Before proceeding with this section, it is recommended that Section 1.2 describing the principle of operation be reviewed for a better understanding of the circuit functions.

The IMF-600 system is first presented in block diagram form and then in detailed schematics (in Section 8) which are related to the various block diagram functions for best clarity.

Refer to the functional block diagram of Figure 7.1. The 1kHz Test Signal which is passed through the unknown is generated by a 1MHz crystal oscillator which is frequency divided to produce a 1kHz square wave. This square wave is in turn filtered by a 1kHz band pass filter to produce a 1kHz sine wave

The 1kHz sine wave is fed through an analog multiplier to set the test signal amplitude as will be described below. This output is then fed to a power amplifier to provide the actual signal which must pass through the unknown impedance, Zx, and the sensing resistor, Rs, in series with it.

When the unknown is a capacitance and/or a conductance, the voltages across Zx and Rs are measured by ac coupled high impedance amplifiers. Vx is input into a Constant AC Amplitude Circuit which drives the analog multiplier to maintain Vx equal to a constant reference. From Section 1.2, we know that C and/or G are therefore proportional to Vs.

In order to "measure" Vs, its real and imaginary components must be separated. To do this, the Vx signal is fed to a Phase Reference Generator to produce two phase reference signals, one in phase with Vx, and the other at 90 degrees phase shift. These two reference signals are in turn used to determine the amplitudes of the two components of Vs, the one in phase with Vx and the one at 90 degrees.

If the device under test is a pure conductance, then the Vs signal is completely in phase with Vx, and the output of the top In Phase Amplitude Detector is zero, representing capacitance, and the lower one is finite representing conductance. If the impedance is a pure capacitance, the Vs signal is 90 degrees out of phase with Vx, and only the top detector will produce an output for capacitance. For a complex impedance, there will clearly be both components.

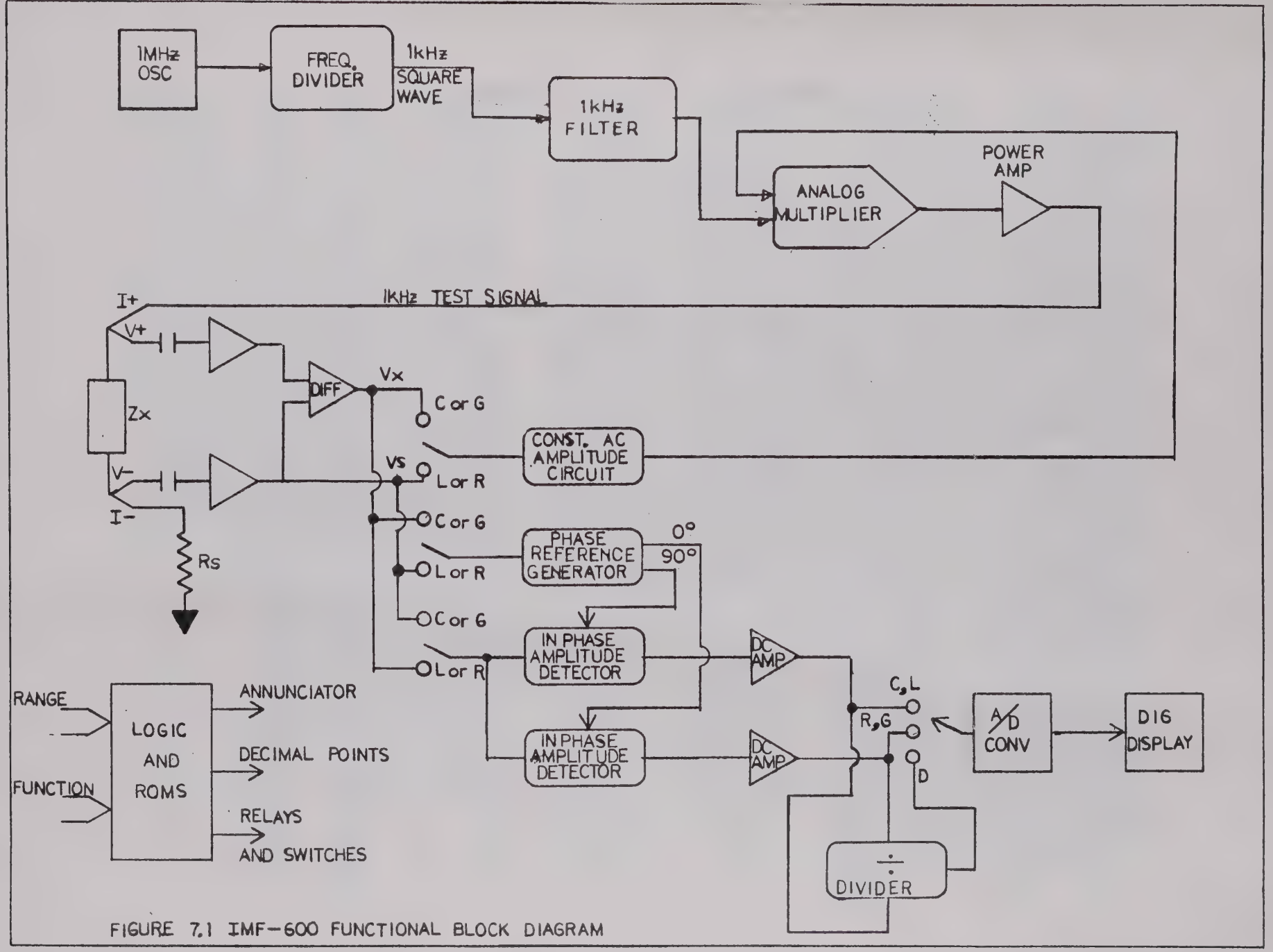


FIGURE 7.1 IMF-600 FUNCTIONAL BLOCK DIAGRAM

For the measurement of inductance and/or resistance, the roles of Vx and Vs are reversed as explained in Section 1.2 and shown in Figure 7.1.

The analog voltages representing C, L, R, or G are fed to an Analog to Digital Converter which drives a 3 1/2 digit display at 1000 counts/volt.

The dissipation, D, is computed by using the A/D converter in the ratiometric mode, when the "D" pushbutton is pressed, to derive a ratio proportional to the real or lossy impedance component to the imaginary one. See Sections 3.9 and 3.10.

The range and function, as determined by the pushbuttons and the rotary switch, control through logic and ROM's (Read Only Memory) the status of the annunciator displays, the decimal points, and various internal circuit functions.

The optional frequency counter is completely independent of the impedance computation scheme and only shares the power supplies and digital display. See the Interconnection Diagram in Section 8.

7.2 Detailed Circuit References

In order to allow for the identification of the various circuit subsystems, Table 7.1 allocates circuit components (which may be found on the schematics in Section 8) to the functions indicated in Figure 7.1 and to other secondary functions.

In the component notation, the first number indicates the printed circuit board number, e.g. 2A14 is A14 or integrated circuit 14 on circuit board IMF-2. See also Figures 8.1-8.2 for reference. Clearly, only the major components are listed to assist in leading to the appropriate area in the schematics. Also note that some integrated circuit packages contain multiple components and appear in more than one function.

Table 7.1. Function Component References

FUNCTION	COMPONENT REFEFRENCES
Power supplies	2X1,X2,A19,A20,A21,A22,A23
1 MHz oscillator	2A24,Y1
Frequency divider	2A24
1kHz bandpass filter	2A25
Analog multiplier	2A27
Power amplifier	2A12,2Q1,Q2
Range encoder	2A1
Function encoder	2A13
ROM's	2A14,A15
Annuciatior drivers	2A16,A17,A18
Input ac coupled amps	1A33,A36,A37
Difference amplifier	1A34
Const ac amplitude circuit	1A5,A6,A9,A10,A11,A27
Phase ref gen, 0 deg, G	1A13,A17
Phase ref gen, 90 deg, C	1A13,A28
Phase ref gen, 90 deg, L	1A18,A23
Phase ref gen, 0 deg, R	1A18,A29
In-phase ampl detect, top	1A15,A16,A21,A22
In-phase ampl detect, bott	1A3,A16,A19,A20
A/D converter	1A30
True RMS converter current	1A31
True RMS converter voltage	5A1
Overrange detector	1A12,A24,A25
Overvoltage protection ckt	1A32,A35,1K3
C1 and L1 gain and zero	1A1,A2
3 1/2 digit display	3A1,A2,A3,A4
Annuciators	3A5,A6,A7,A8,A9
Voltage divider	Rotary switch board
Current divider	Rotary switch board

8.0 MAINTENANCE

****

DANGEROUS VOLTAGES EXIST WITHIN THIS INSTRUMENT. MAINTENANCE INSTRUCTIONS IN THIS OR ANY ASSOCIATED MANUAL ARE FOR USE BY QUALIFIED SERVICE PERSONNEL ONLY. TO AVOID ELECTRICAL SHOCK, DO NOT ATTEMPT ANY SERVICING OTHER THAN CALIBRATION UNLESS YOU ARE QUALIFIED TO DO SO.

****

8.1 Disassembly Procedure

Follow this procedure carefully in order to be able to reconnect all cables and circuit cards correctly:

1. Unplug the unit from the AC power line.

2. Remove the four (4) screws from the bottom of the unit.

3. Carefully pull off the top cover.

4. For units with frequency option, the top circuit card IMF-4 must first be removed. Do this by unscrewing the four nuts holding it in place. It may then be pulled aside with its cables still connected.

5. Carefully, but firmly, pull off the two colored top side panels and the two black middle side panels.

6. Remove the RANGE knob and the nut holding the rotary switch to the front panel. The rotary swith circuit card may now be pulled aside with its cables still connected. The nut and knob should be returned in order to operate the roraty switch.

7. Using a pair of pliers or a socket driver, remove the four (4) nuts holding the top circuit card IMF-1.

8. Pull out the front panel, along with circuit card IMF-1 out of the case and lay them down to the right of the case. If necessary for better component separation, push the Kelvin test leads into the panel to loosen them.

9. At this point, you may wish to cover the front panel with something to protect it from being scratched while any maintenance is being performed.

10. If required, the bottom circuit card, IMF-2, may be removed by unscrewing the four screws holding it to the bottom of the case. The rear panel may also be removed at this point.

8.2 Reassembly Procedure

Figure 8.1 shows the system cable interconnections as they exist without the frequency cicuit. Figure 8.2 shows them with the frequency circuit. Observe the correct position for pin 1 on all connectors. Connectors with no pin 1 indicated may be inserted either way.

1. If you wish to test the system before reassembling, make certain that no AC power points are exposed and that the circuit cards are electrically separated. SINCE A SHOCK HAZARD EXISTS, THIS SHOULD ONLY BE DONE BY QUALIFIED PERSONNEL. Turn on the system and test the various functions in accordance with the instruction manual. If there is a problem, unplug the unit and examine the cabling, the connections, and any service modifications.

2. If it has been removed, screw on circuit card IMF-2.

3. Replace the two colored bottom side panels.

4. Insert the rear panel in place.

5. Pull out the Kelvin test leads to the original position.

6. Position or route the various cables. Cables "JA", "J2S" and "JM" come from the back of IMF-2. Cable "JD" comes from the left side.

7. Insert the pushbutton swithes into the front panel, and carefully insert cicuit card IMF-1 along with the front panel into the case. Make certain that no cables or other components are pinched.

8. Screw on the four (4) nuts, along with lock washers, that hold down IMF-1.

9. Insert the two black side panels. Make certain that they go down all the way.

10. Insert the two colored side panels.

11. Fold and position the various cables neatly.

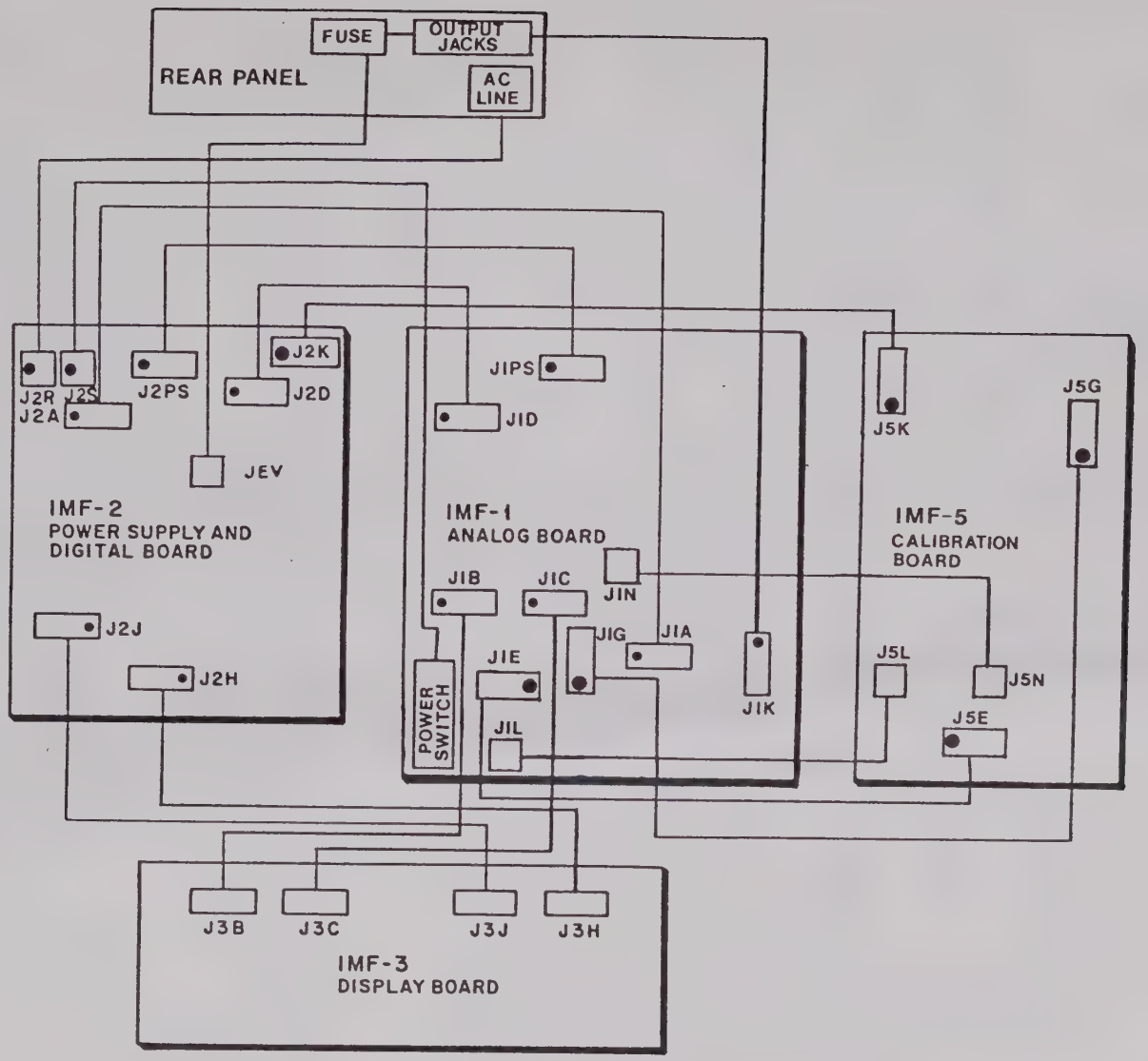


Figure 8.1 System Cabling without Frequency Circuit

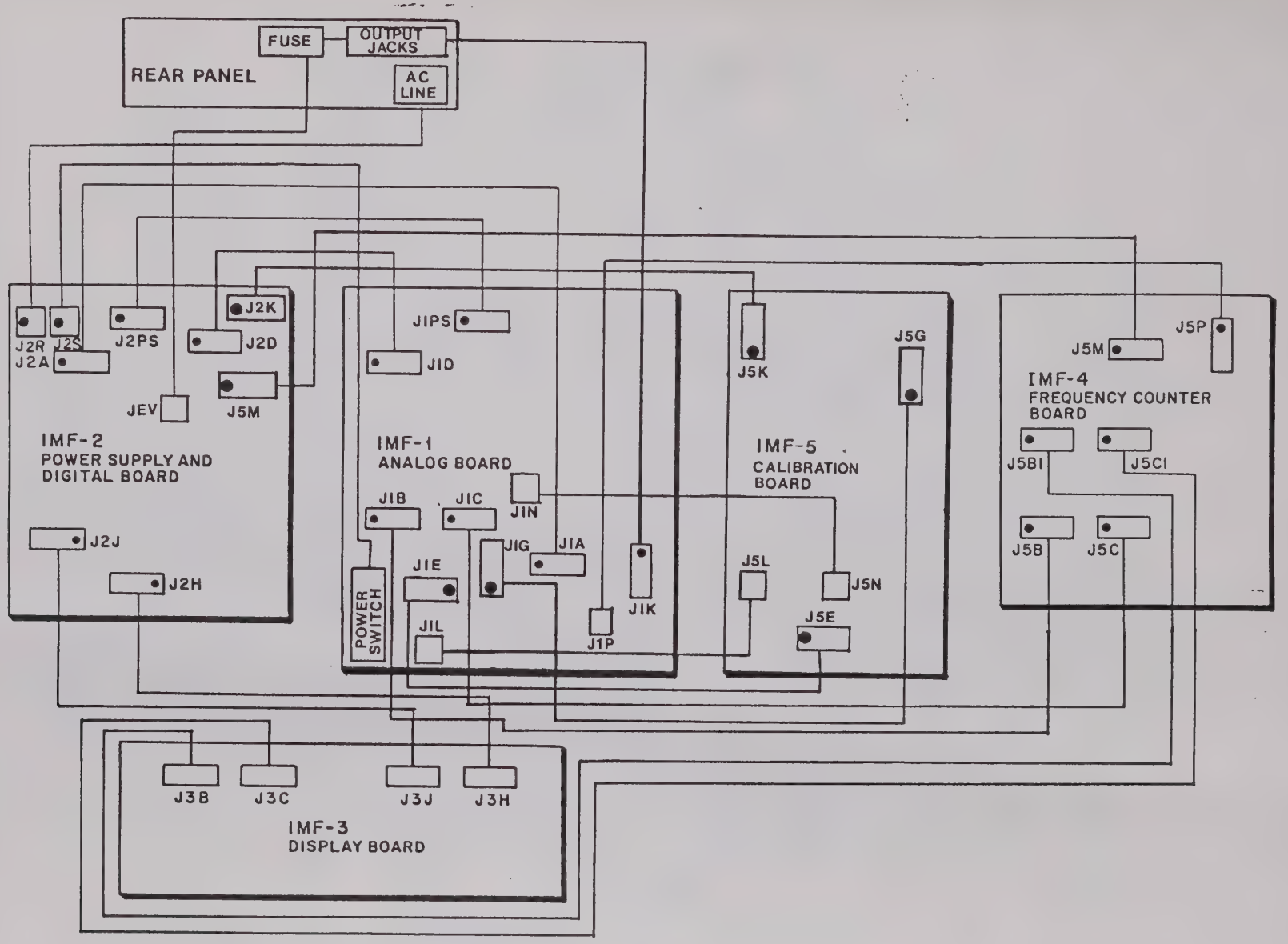


Figure 8.2 System Cabling with Frequency Circuit

12. Install the rotary switch circuit card. Be careful not to mar the front panel when tightening the nut. Replace the knob and align the pointer.

13. Mount the optional frequency circuit card, IMF-4, if present.

14. Replace the top cover and the four bottom screws.

8.3 Troubleshooting

8.3.1 Initial Troubleshooting

The IMF-600 is a complex instrument due to the many functions tht it performs. In case of difficulty, begin by checking the following items:

Is one of the function pushbuttons depressed?

Is the AC line fuse on the rear panel good?

Is the protection fuse on the rear panel good?

Is the current fuse on the rotary switch circuit board good?

Is the unknown being measured according to the instructions?

8.3.2 Service Hierarchy

In servicing the IMF-600, it is important to know which functions are operational in order for subsequent functions to work properly. Generally the following priorities are in effect:

-AC fuse on rear panel

-Protection fuse on rear panel

-Power supplies

-A/D converter or DC voltage

-1 kHz test signal

-Constant ac amplitude circuit

-Phase reference and detector circuits

-C, G, L, and R funtions

-D circuit

Special items:

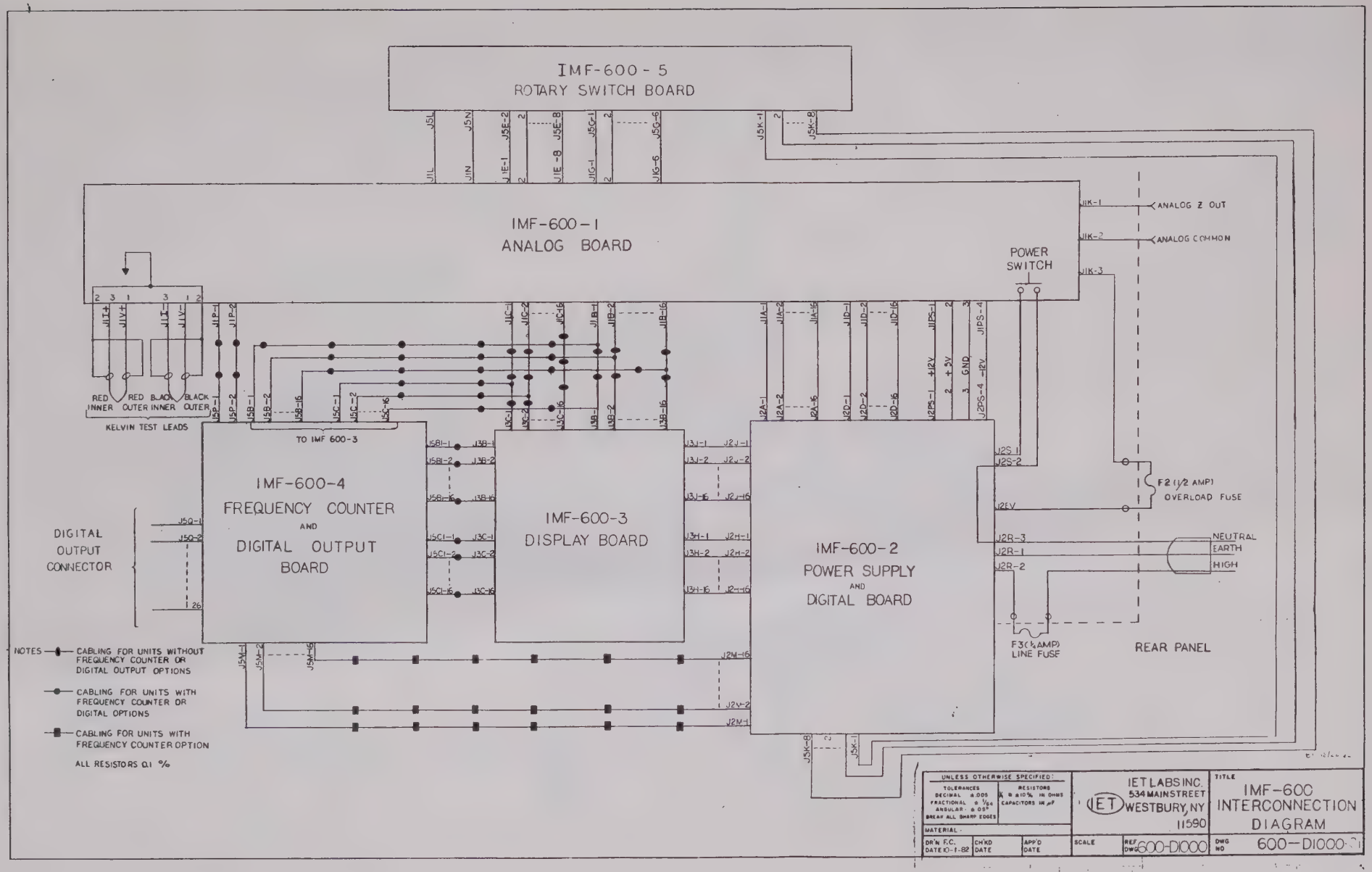
-Current function requires operational DC voltage and current fuse.

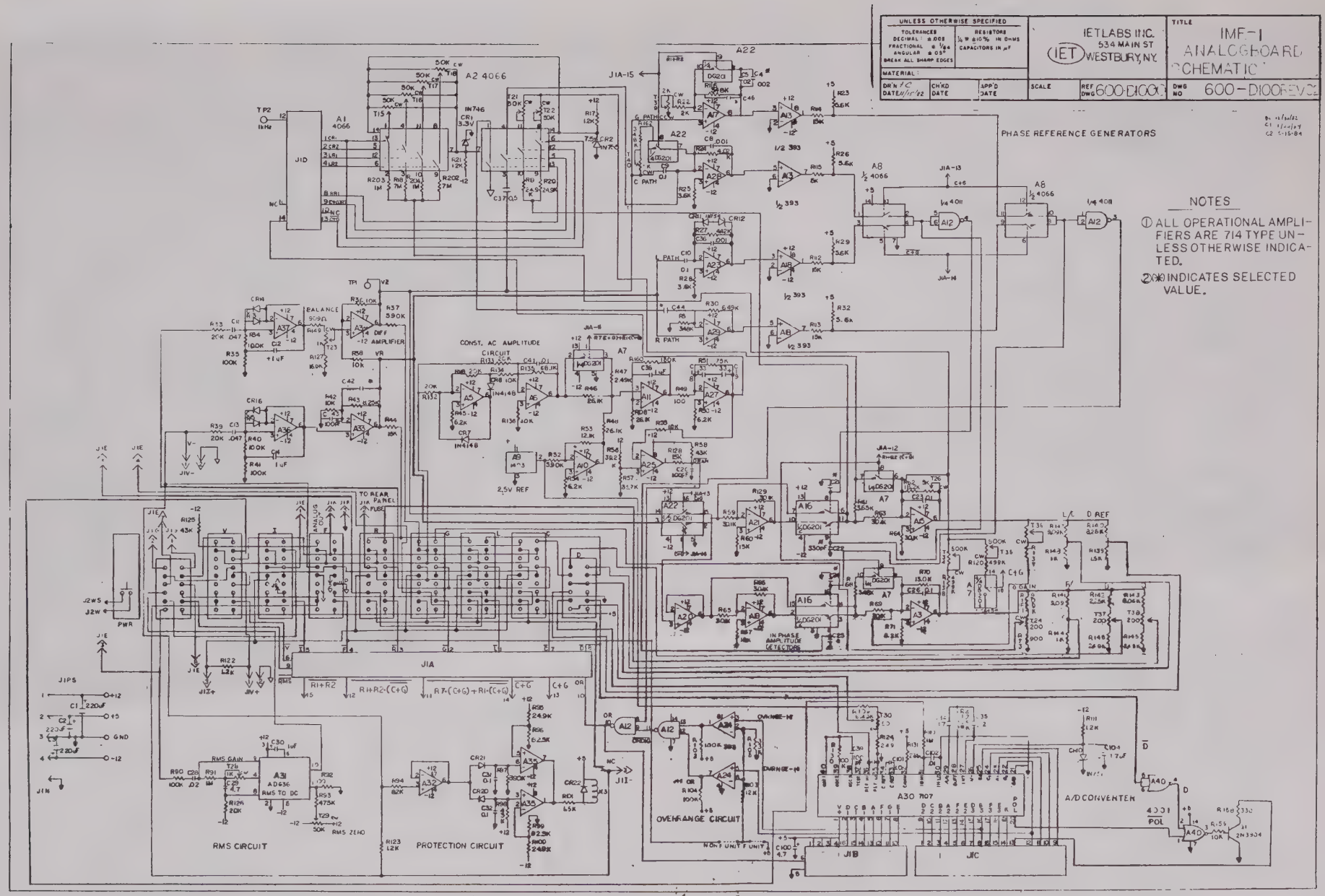
-AC voltage requires operational DC voltage.

-Frequency counter requires operational power supplies and 1kHz square wave generator.

8.4 Circuit Diagrams

The schematicas in this manual may vary slightly from any particular unit due to improvements that may have been incorporated.


IMF-600-5
ROTARY SWITCH BOARD
IMF-600-1
ANALOG BOARD
ANALOG Z OUT
ANALOG COMMON
POWER SWITCH
RED INNER
RED OUTER
BLACK INNER
BLACK OUTER
KELVIN TEST LEADS
TO IMF 600-3
IMF-600-4
FREQUENCY COUNTER
AND
DIGITAL OUTPUT
BOARD
IMF-600-3
DISPLAY BOARD
IMF-600-2
POWER SUPPLY
AND
DIGITAL BOARD
DIGITAL
OUTPUT
CONNECTOR
F2 (1/2 AMP)
OVERLOAD FUSE
NEUTRAL
EARTH
HIGH
F3 (1/2 AMP)
LINE FUSE
REAR PANEL
NOTES
CABLING FOR UNITS WITHOUT FREQUENCY COUNTER OR DIGITAL OUTPUT OPTIONS
CABLING FOR UNITS WITH FREQUENCY COUNTER OR DIGITAL OPTIONS
CABLING FOR UNITS WITH FREQUENCY COUNTER OPTION
ALL RESISTORS 0.1 %
UNLESS OTHERWISE SPECIFIED:
IET LABS INC.
534 MAINSTREET
WESTBURY, NY
11590
TITLE
IMF-600
INTERCONNECTION
DIAGRAM
MATERIAL
DR'N F.C.
DATE 10-1-82
CH'KD
DATE
APP'D
DATE
SCALE
REF DWG 600-D1000
DWG NO 600-D1000-1


UNLESS OTHERWISE SPECIFIED
TOLERANCES
DECIMAL: ±.005
FRACTIONAL ± 1/64
ANGULAR ± 0.5°
BREAK ALL SHARP EDGES
RESISTORS
1/4 W ±10% IN OHMS
CAPACITORS IN µF
MATERIAL:
DR'N J.C.
DATE 8/16/82
CH'KD
DATE
APP'D
DATE
IETLABS INC.
534 MAIN ST
WESTBURY, NY
IET
SCALE
REF DWG 600-D1003
TITLE
IMF-1
ANALOG BOARD
SCHEMATIC
DWG NO 600-D1001 REV C2
PHASE REFERENCE GENERATORS
NOTES
① ALL OPERATIONAL AMPLIFIERS ARE 714 TYPE UNLESS OTHERWISE INDICATED.
② INDICATES SELECTED VALUE.
A2 4066
A1 4066
A22
A8 1/2 4066
1/4 4011
1/2 393
A7
A16
A5
A6
A11
A27
A25
A10
A3
A30 7107
A/D CONVENTER
A40
A31 AD636 RMS TO DC
RMS CIRCUIT
PROTECTION CIRCUIT
OVERRANGE CIRCUIT
A/D CONVERTER
CONST. AC AMPLITUDE CIRCUIT
IN PHASE AMPLITUDE DETECTORS
TO REAR PANEL
JIA
JIB
JIC
JID
JIE
JIF
JIN
JIPS
J2W
J2WS
PWR
2.5V REF
RMS ZERO
RMS GAIN
OVRNGE-HI
OVRNGE-LO
NON-UNITY
UNITY
GND
POL

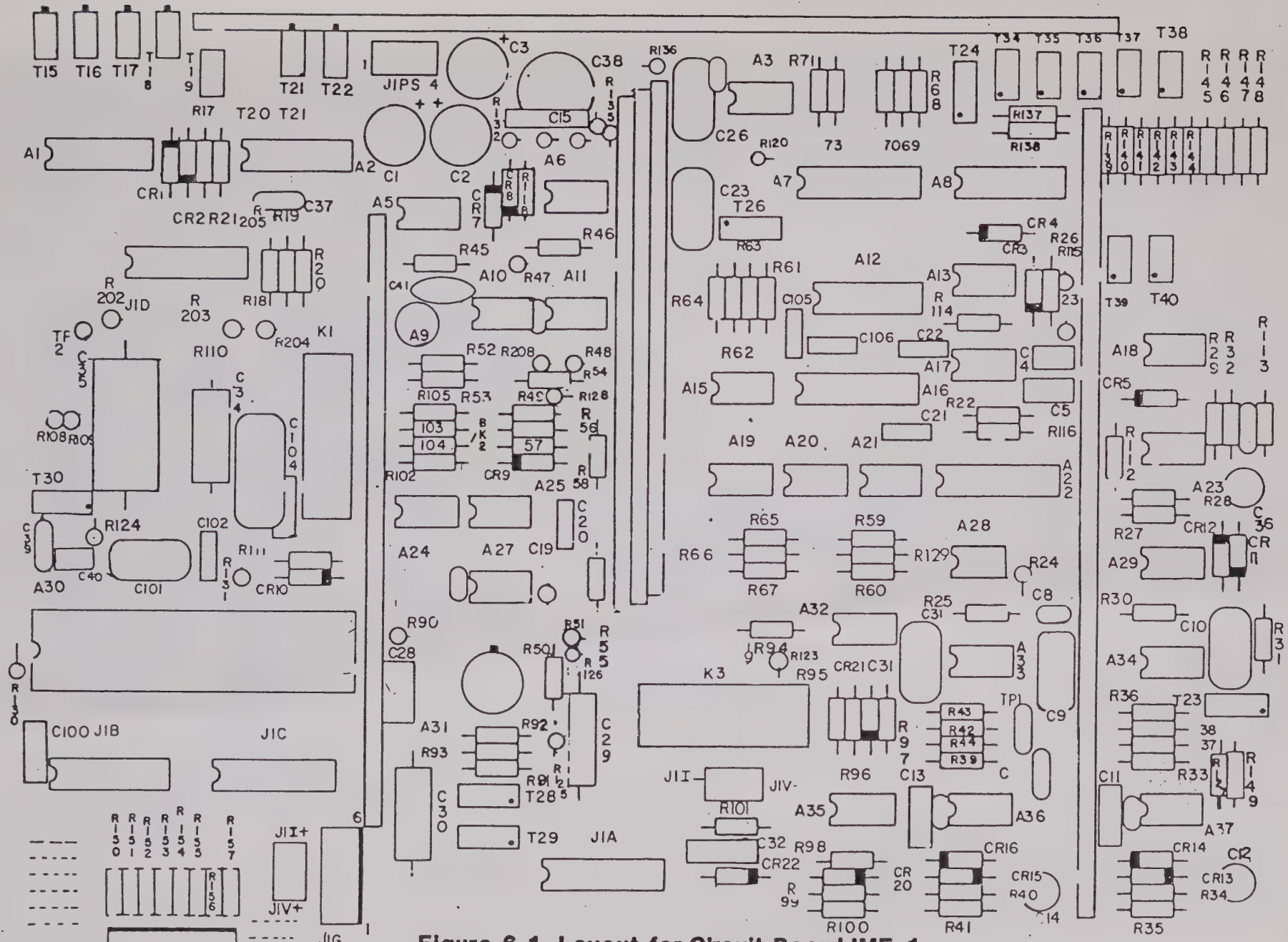
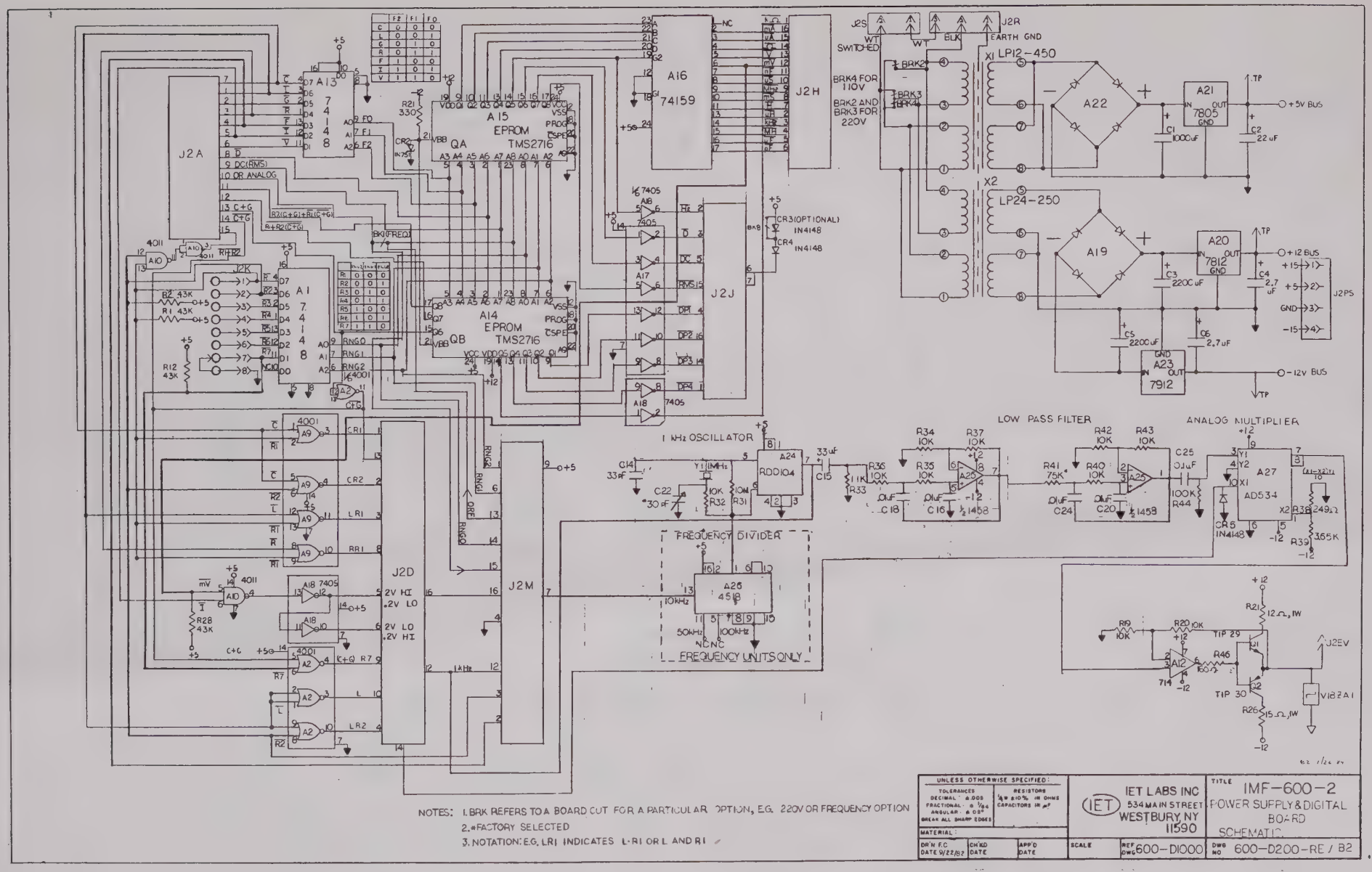
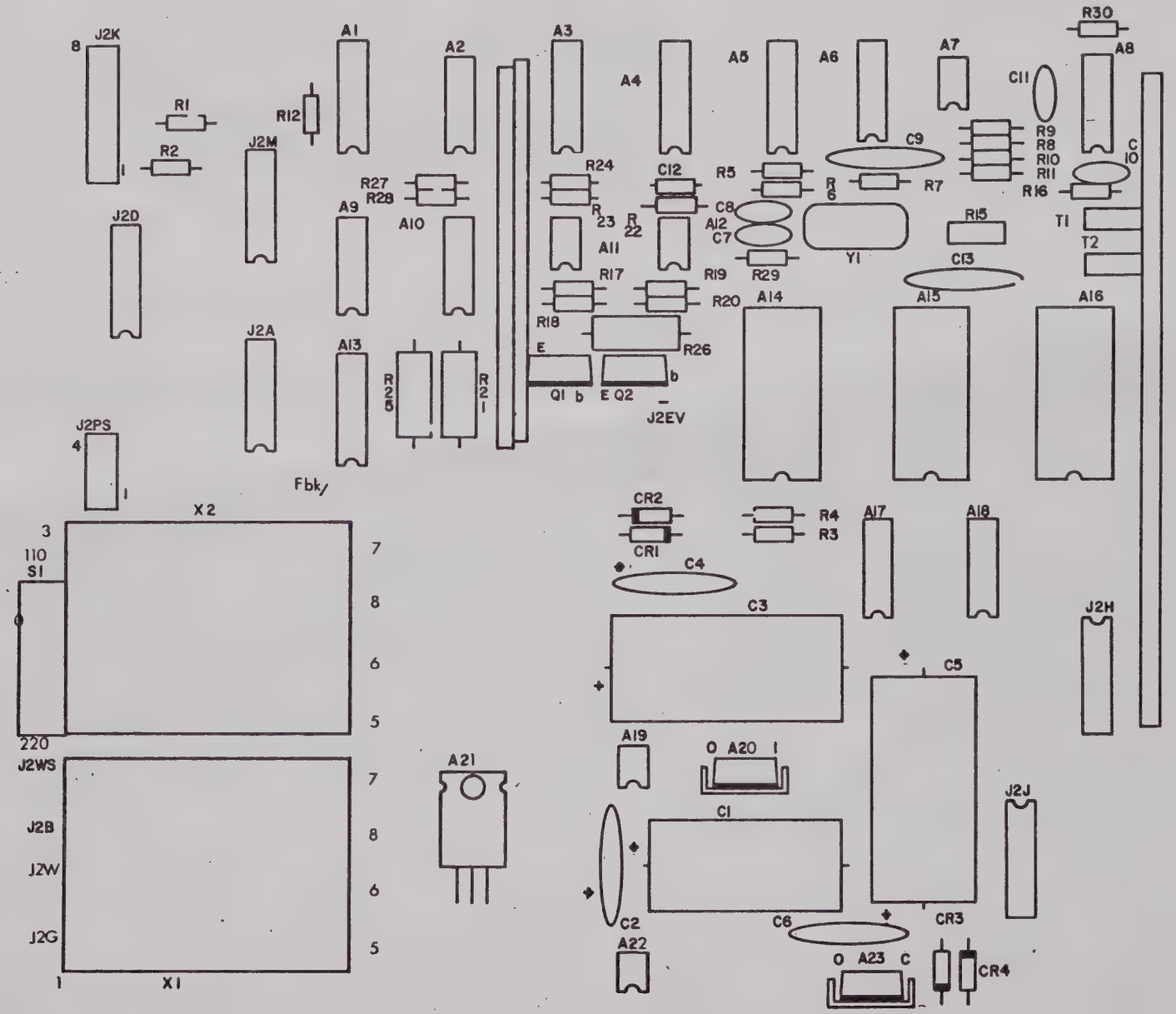


Figure 6.1 Layout for Circuit Board IMF-1

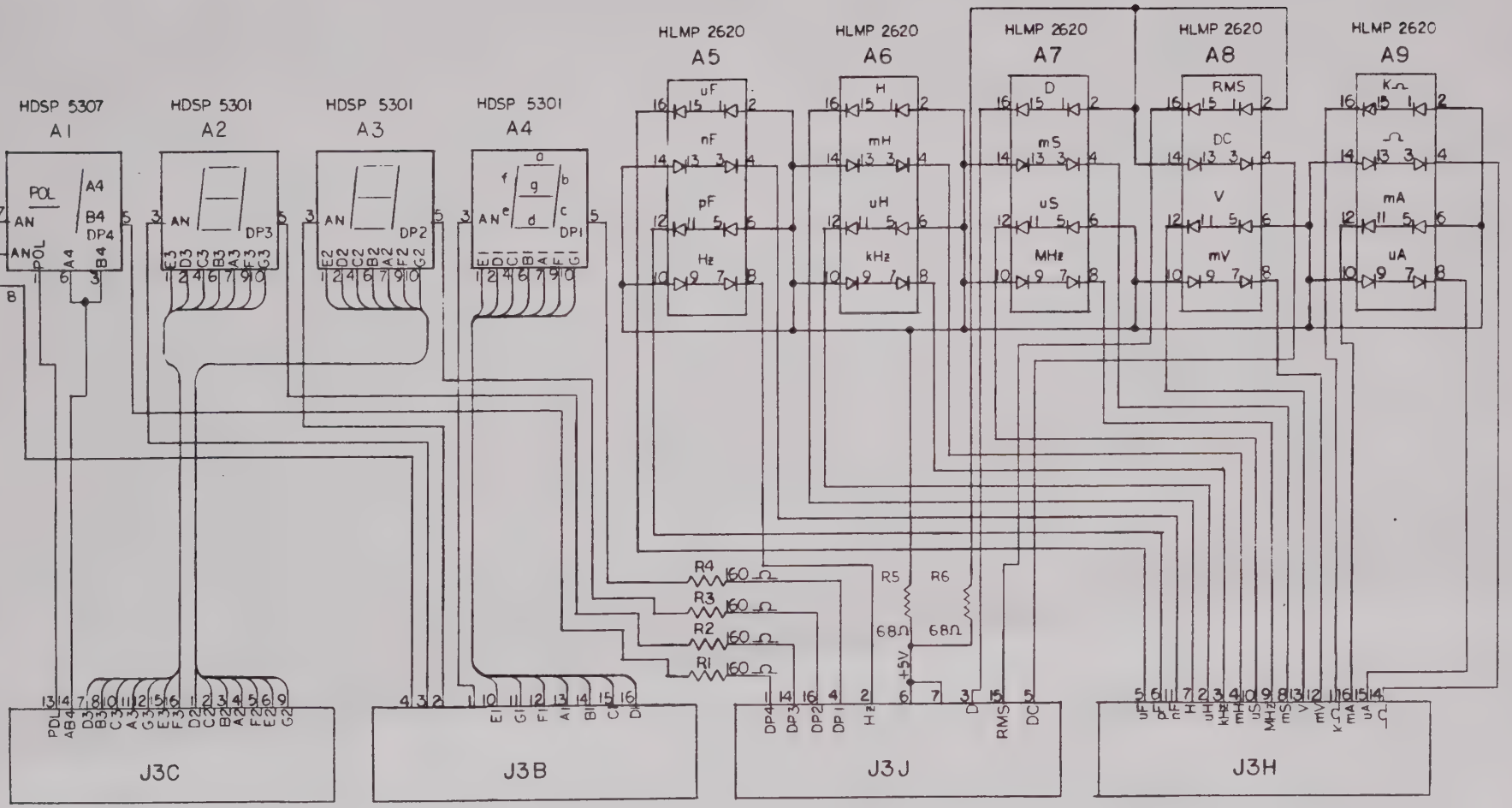


NOTES: 1. BRK REFERS TO A BOARD CUT FOR A PARTICULAR OPTION, E.G. 220V OR FREQUENCY OPTION
2. * FACTORY SELECTED
3. NOTATION: E.G. LR1 INDICATES L-R1 OR L AND R1

UNLESS OTHERWISE SPECIFIED: TOLERANCES DECIMAL: ± .005 FRACTIONAL: ± 1/64 ANGULAR: ± 0.5° BREAK ALL SHARP EDGES; RESISTORS ¼ W ±10% IN OHMS CAPACITORS IN μF; MATERIAL:	IET LABS INC 534 MAIN STREET WESTBURY, NY 11590	TITLE: IMF-600-2 POWER SUPPLY & DIGITAL BOARD SCHEMATIC
DR'N F.C. DATE 9/22/82; CH'KD DATE; APP'D DATE	SCALE	REF DWG 600-D1000; DWG NO 600-D200-RE / B2

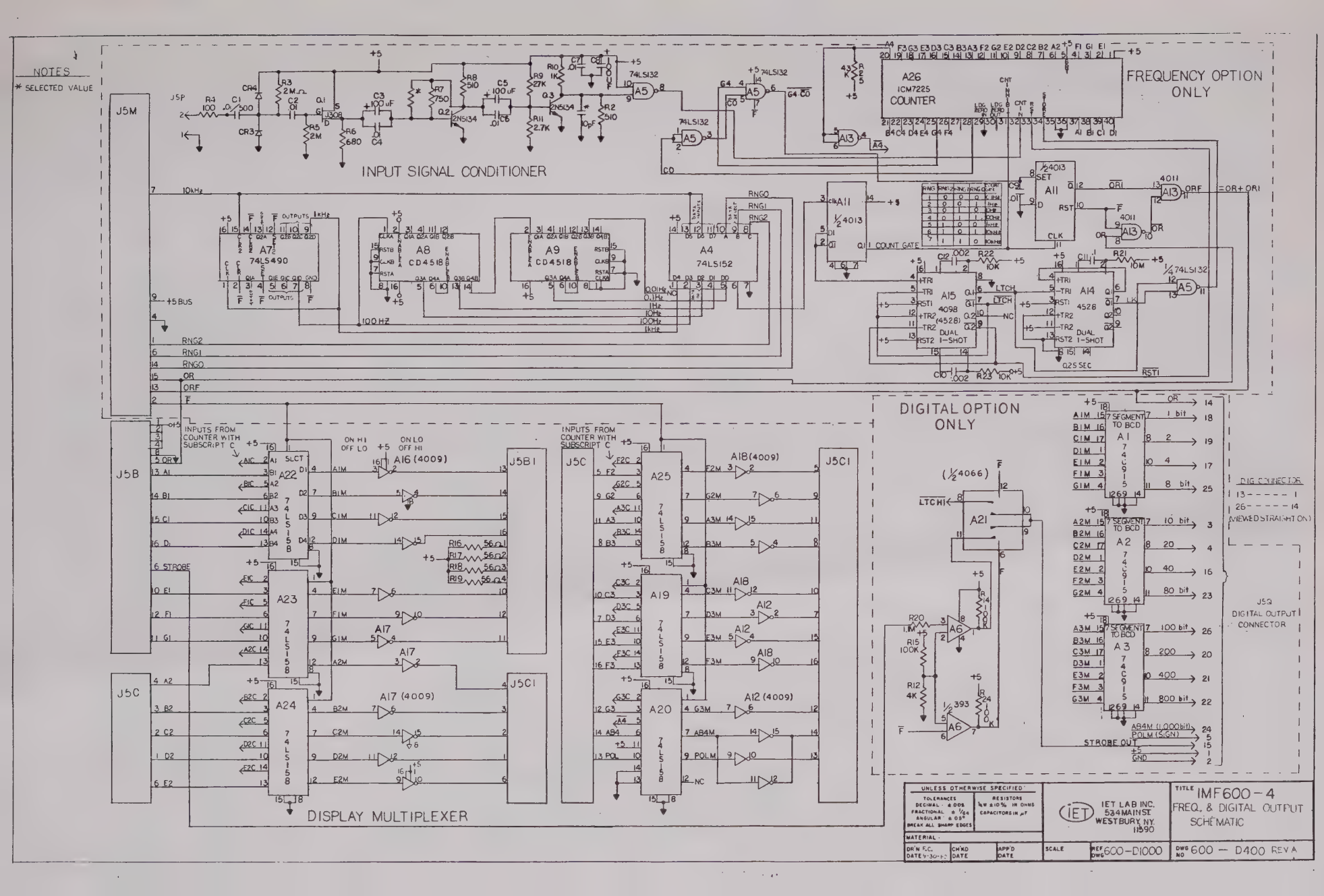


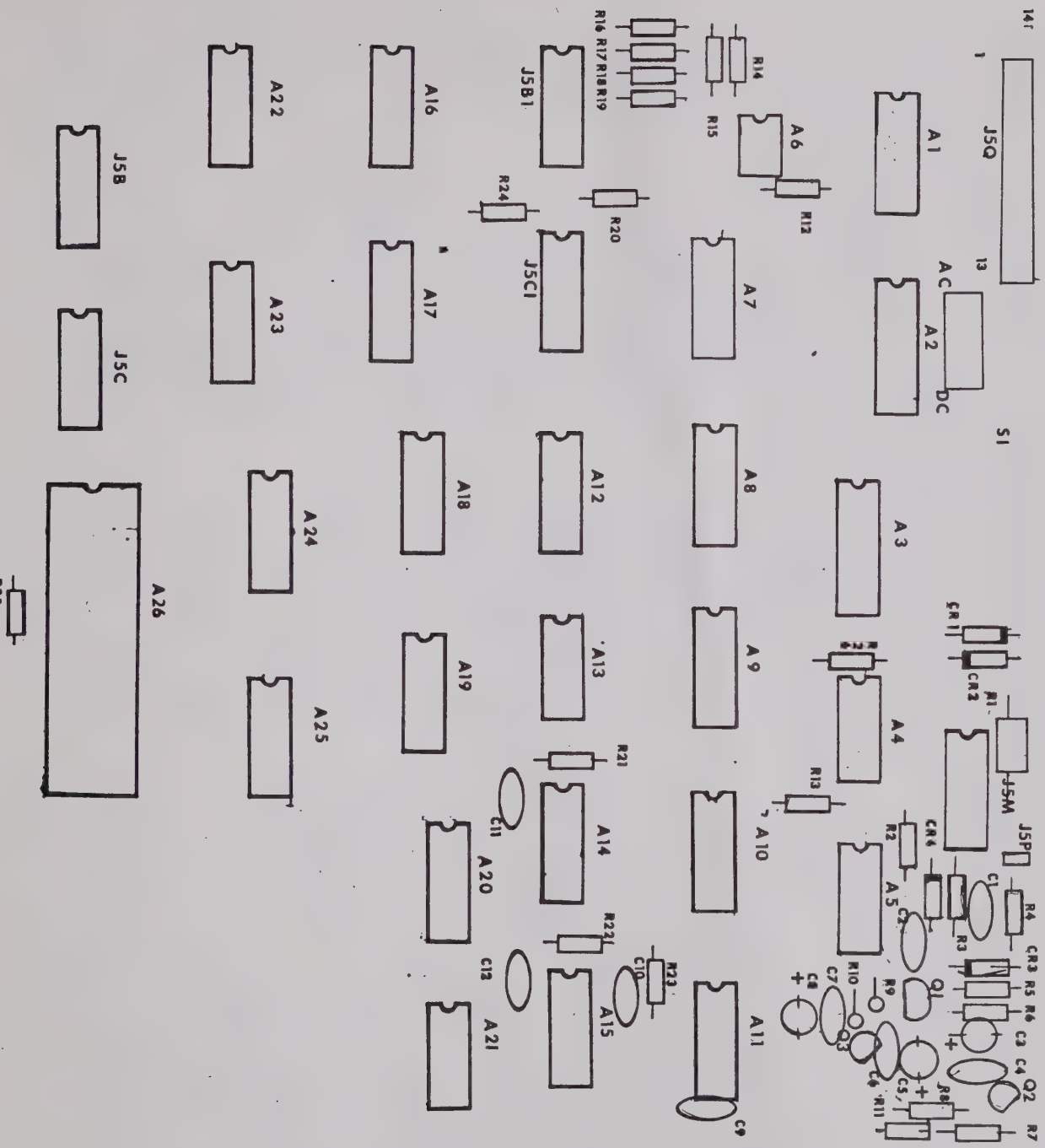
IMF-2 Component Layout



D1 6-5-84

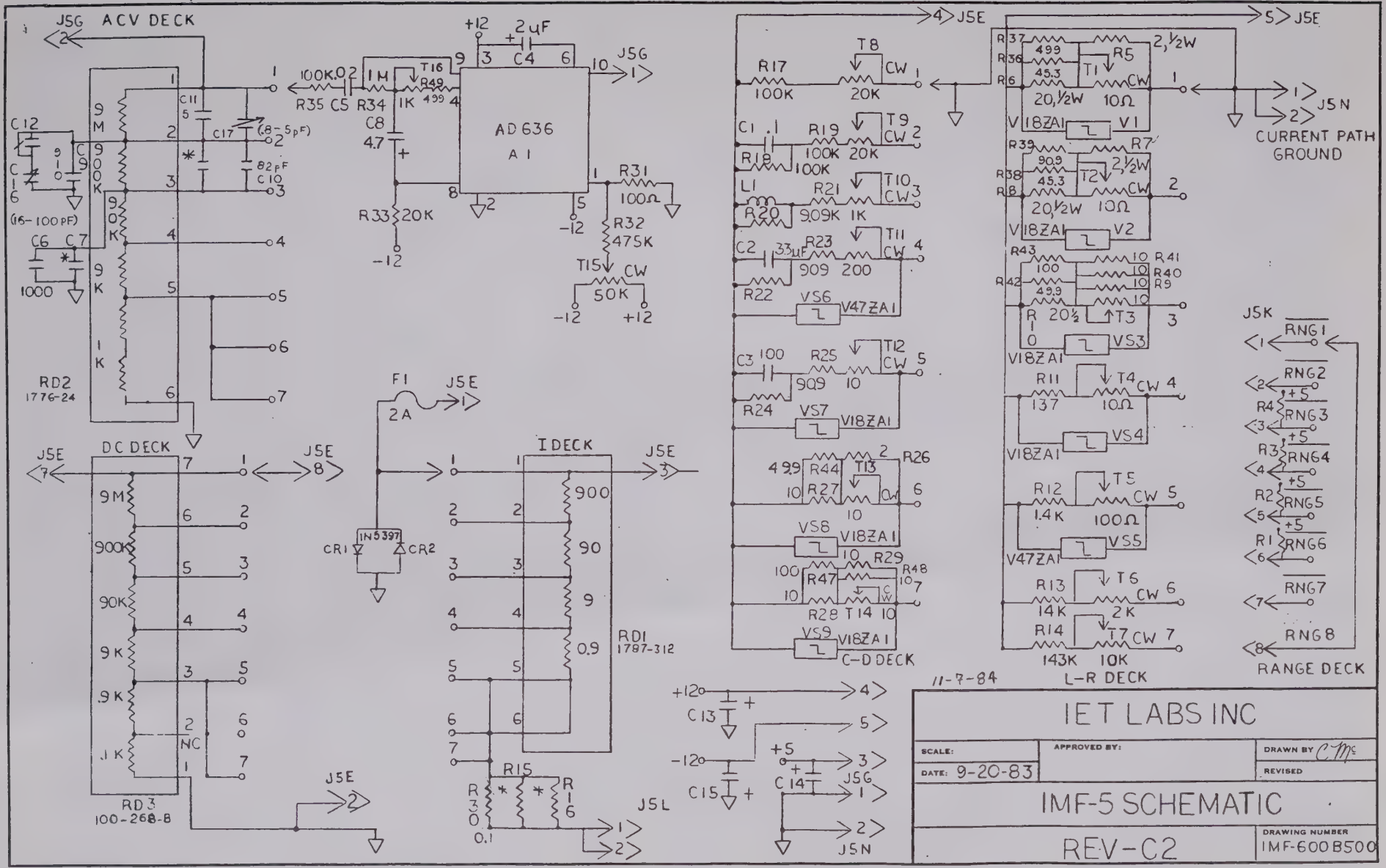
UNLESS OTHERWISE SPECIFIED: TOLERANCES DECIMAL ± .005 FRACTIONAL ± 1/64 ANGULAR ± 0.5° BREAK ALL SHARP EDGES; RESISTORS ¼ W ±10% IN OHMS CAPACITORS IN μF	IET LABS, INC. 534 Main Street WESTBURY, NY 11590	TITLE: IMF 600-3 DISPLAY BOARD SCHEMATIC			
MATERIAL					
DR'N F.C. DATE 9/20/82	CH'KD DATE	APP'D DATE	SCALE	REF DWG 600-D1000	DWG NO IMF600-C300 REV D1


NOTES
* SELECTED VALUE
INPUT SIGNAL CONDITIONER
FREQUENCY OPTION ONLY
A26 ICM7225 COUNTER
DIGITAL OPTION ONLY
DISPLAY MULTIPLEXER
INPUTS FROM COUNTER WITH SUBSCRIPT C
ON HI OFF LO
ON LO OFF HI
J5M
J5B
J5C
J5B1
J5C1
J5Q DIGITAL OUTPUT CONNECTOR
DIG CONNECTOR
VIEWED STRAIGHT ON
IET LAB INC.
534 MAIN ST.
WESTBURY, NY.
11590
TITLE IMF600-4
FREQ. & DIGITAL OUTPUT
SCHEMATIC
UNLESS OTHERWISE SPECIFIED
TOLERANCES
DECIMAL ± .005
FRACTIONAL ± 1/64
ANGULAR ± 0.5°
BREAK ALL SHARP EDGES
RESISTORS ¼W ±10% IN OHMS
CAPACITORS IN µF
MATERIAL
DR'N F.C. DATE 4-30-85
CH'KD DATE
APP'D DATE
SCALE
REF DWG 600-D1000
DWG NO 600 — D400 REV A



UNLESS OTHERWISE SPECIFIED: TOLERANCES DECIMAL: ±.005 FRACTIONAL: ± 1/64 ANGULAR: ± 0.5° BREAK ALL SHARP EDGES		TITLE	IMF-4 FREQ DIGOUT BOARD
			IET LABS
MATERIAL SILKSCREEN			
DR'N FHG DATE 1/12/82 / CH'KD DATE / APP'D DATE	SCALE	REF DWG	DWG NO IMF-600-4 / REV. O

IMF-4 Component Layout



11 x 17 PRINTED ON NO. 1000H CLEARPRINT

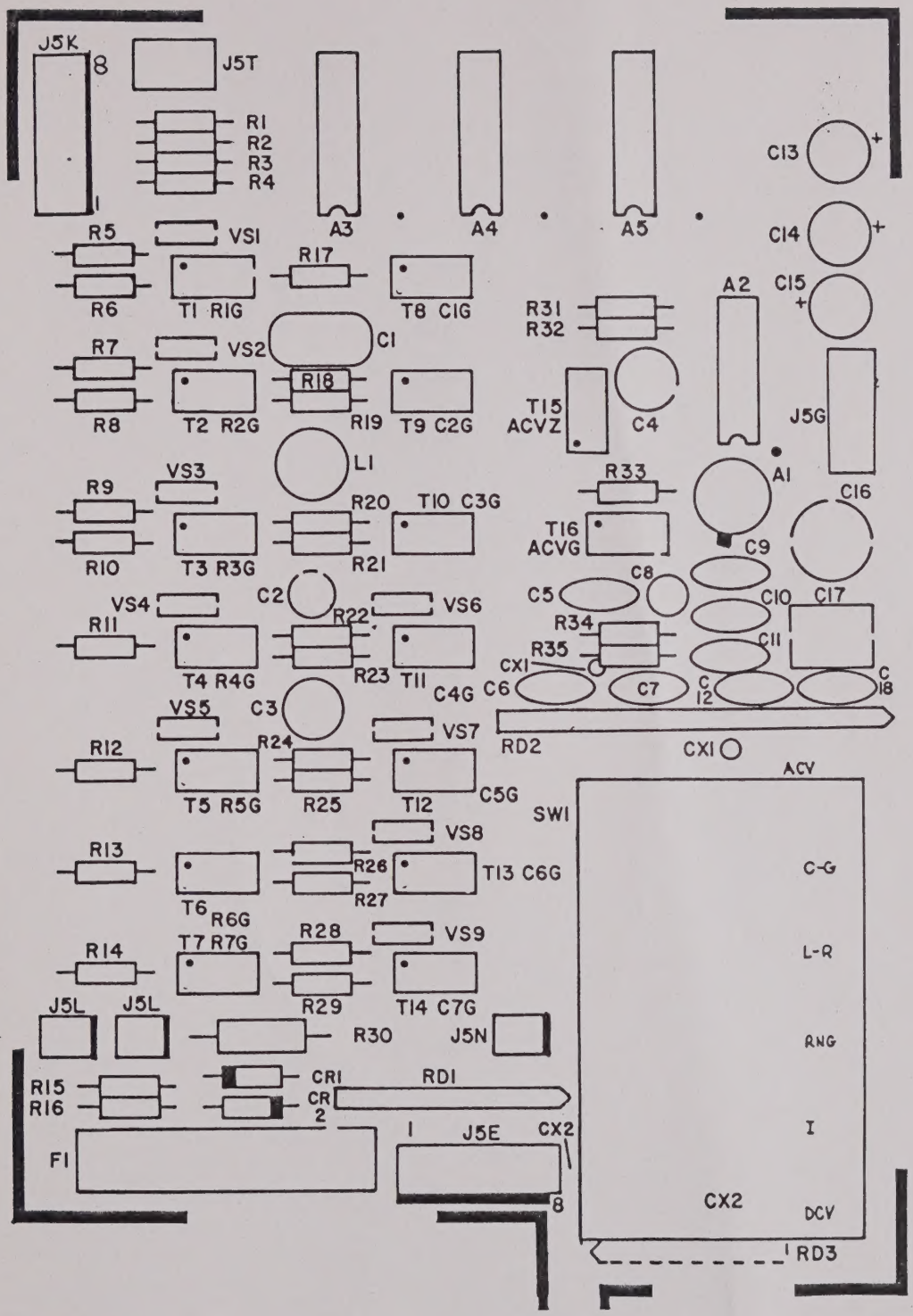
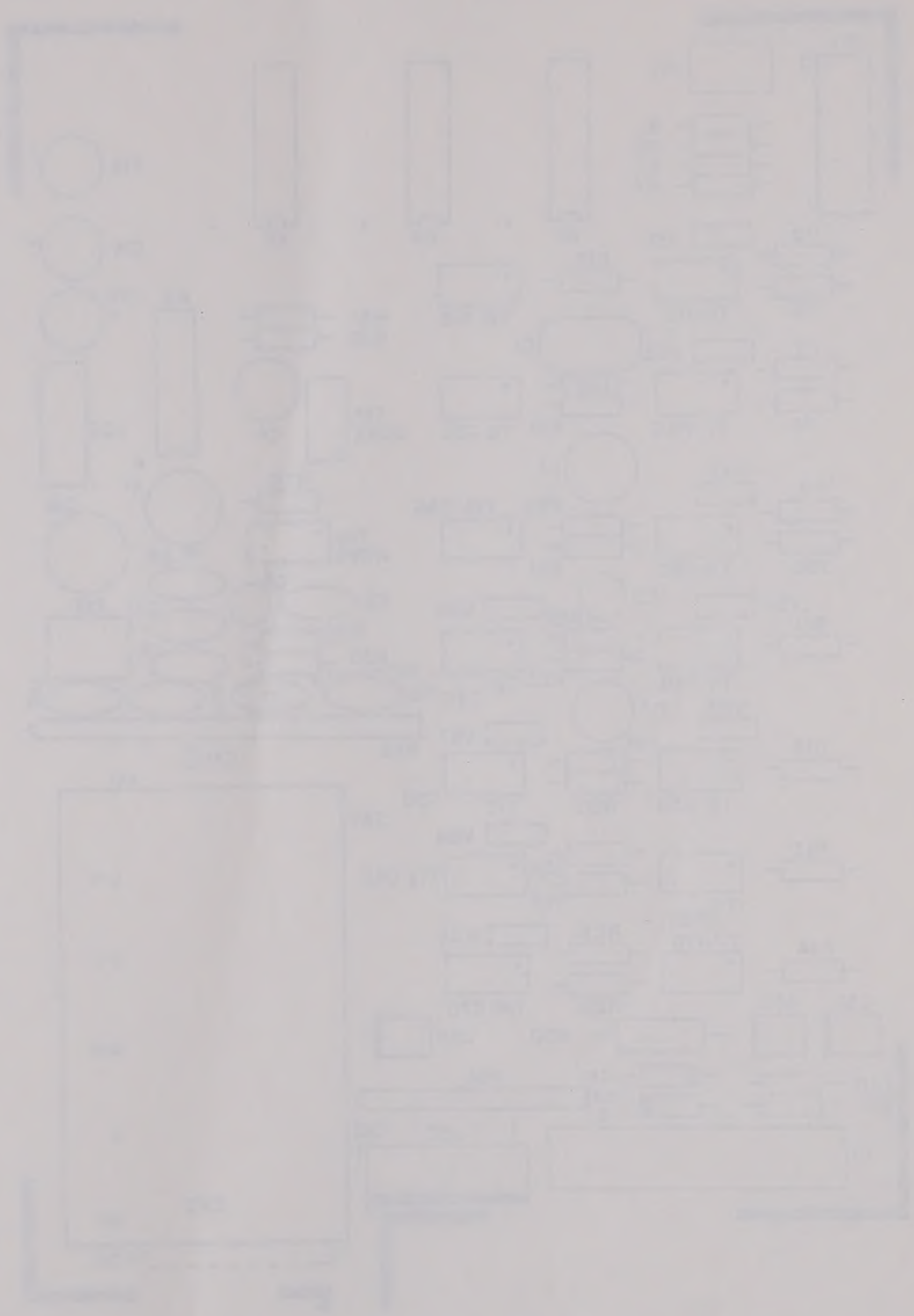


Figure 6.2 Layout for Circuit Board IMF-5



MP MASTER
MA35003